

The Renewable Electron Economy: A Summary for Policymakers

Michael Hoexter, Ph.D.
Terraverde Consulting
Belmont, CA, USA

Part 1. Building the Renewable Electron Economy as a Solution to the Oil Crisis (Transport)

Part 2. Supplying Clean Energy

Part 3. Economic and Policy Drivers for Clean Energy and Transport Infrastructure

Part 4. Energy Efficiency and Conservation and the Renewable Electron Economy

(August- October 2008)

(also available on the web at <http://greenthoughts.us/policy/reesummary/>)

I. Building the Renewable Electron Economy as a Solution to the Oil Crisis

(originally published August 4, 2008)



Lines formed at gas stations during the 1973 OPEC oil embargo. In the near future, rationing is more likely to take the form of high prices rather than through limits on consumption.

This is the first in a short series on how we can build an energy future based on our best science and no longer critically dependent upon exhaustible and polluting fossil fuels.

Too often, discussions of our future energy system simply reflect the current array of political forces in Washington or the novelty-hungry attention of the media and not the long-term viability of technologies and proposed solutions. As the price of oil is the most pressing issue from a short-term perspective, I am starting this series of policy briefs with how the energy used in transport on land can be transferred from liquid fossil fuels to cleanly generated electricity; in the second part I will address how we can create the conditions for powering the grid in the post-fossil fuel era.

Oil Supply: Speculation and Long-Term Trends

We can all now agree that it has been the ultimate in shortsightedness to continue building a society founded upon burning ever increasing amounts of easily exhaustible resources. Not only is it highly visible petroleum at the pump but, behind the scenes, the vital energy for agriculture and freight transport that now depend upon the output of oil wells, mostly located abroad. In the US in particular, we have had a twenty-five year hiatus in facing this reality through political, cultural and corporate resistance to change,

which means that Americans are starting the race far behind the starting line. In addition, as it turns out, the burning of these fossil resources alters the global climate and creates local pollution and health problems. There are other ills and challenges in our world but currently fossil fuel addiction is one of the most pressing but also, fortunately, soluble problems.



Talk of a speculative bubble in oil is a distraction from the fundamental reality of a widening gap between increasing transport energy demand and static or dwindling supply of liquid hydrocarbons. Those who put their faith in speculation as the driver of punitively high oil prices come from two divergent camps. Some are wedded to the energy status quo by a conservative, jaded view of energy alternatives and function as defenders of the fossil fuel energy industry establishment (the business commentator

Larry Kudlow comes to mind). A more surprising group are populists and left-leaning analysts who always use the formula “qui bono” (who benefits) to locate the responsible parties for any social ill. These critics of oil companies and oil sheiks continue to promote the illusion of an endlessly abundant and forgiving Nature, which is despoiled not by our combined global thirst for energy but solely by a thin layer of greedy profiteers, who can be punished or pushed aside thereby making the problem go away. We can safely expect oil to continue to climb in price even if we are now currently in a period where emotions have driven prices higher than actual supplies would warrant as some continue to profit from the price run-up.

Beyond speculation, suggestions that we can drill and refine our way out of the inevitable decline of oil that we have known for a long time to be in finite supply anyway, function as populist pandering or as short-term profit-maximizing calculus by parts of the oil industry. Members of the latter group, in a profits-over-ethics mode, would like us to continue to depend on oil as long as it is profitable for oil producers, which will be the case until a fundamental break with petroleum use in transportation is organized; obviously scarcer but more expensive oil will continue to be a cash cow unless a new post-oil transport system has been built. There is fundamental conflict between backward-looking portions of the petroleum industry and the general health of our economy and environment, a conflict which must be decisively resolved by policymakers and the voting and buying public in favor of new, cleaner energy sources in the next few years.

On the other hand, realistically, oil production and supply will need to remain a concern for a few more decades, yielding a very delicate but extremely important political challenge. On the political side, Republican Presidential candidate John McCain has relied on common wishes that more domestic oil production through offshore drilling will somehow eliminate or significantly soften the inevitable price spiral upward. Such drilling will only have an impact 10 years hence at a point when worldwide demand will have still further outstripped supply and prices will be in a comparative sense stratospheric. Not quite drawing a clear political front on this issue, Barack Obama has lately been attempting to accommodate the popular appeal of offshore drilling by [suggesting that new drilling would support energy alternatives](#).



Oilman T. Boone Pickens has turned his attention to natural gas and wind

Natural gas with its lower carbon dioxide emissions per unit energy is occasionally touted as an “alternative” fuel but it too can easily be exhausted; in fact, production in [natural gas wells tapers off very rapidly](#) as compared to its solid and liquid fossil brethren, making price spikes and shortages all the more likely in a turn to natural gas. The stock-picker [Jim Cramer praises natural gas](#) as an investment and [T. Boone Pickens](#), in his [new heavily marketed energy plan](#), trumpets it as an automotive fuel, as we are sure to use more of this dwindling lower-carbon resource, but it is not a sustainable alternative to oil. Relying on natural gas as a climate or energy solution is the modern definition of a Faustian bargain: highly profitable for some but costly for most economic sectors, our society as a whole and our atmosphere.

Differentiating Short-Term and Long-Term Solutions



Depending on oil has discouraged planning in the area of energy and transportation.

The impulse to jump on the natural gas or intensified oil exploration bandwagons will distract policymakers by confusing short-term and longer-term solutions. Fluctuations in supply of these hydrocarbons may create a temporary plateau in prices but no enduring relief. In the short-term, within the next two or three years, steps can be taken to ameliorate what may be, in the energy and transport areas, a grim period. It is here that I part company with some of the doom-and-gloom predictions about economic collapse that originate from some Peak Oil enthusiasts. While I agree with some of the more pessimistic predictions about oil and natural gas supply and pricing, there are short-term, rapidly deployable solutions at least for passenger travel and some freight that will soften the blow.

Effective short-term solutions include

1. Fiscal support for intensified operations by existing public transport – Federal and state governments will need to help local and regional transit agencies to increase their schedules to serve more riders without raising ticket prices substantially.
2. Development of Internet- and cellphone-based ride sharing businesses and services. Local development of van-pooling services also enabled by Internet and cellphone-networks.
3. Development of transport centers or nodes for public transit and ride sharing with municipal and regional oversight to increase efficiency and security.
4. Opening of lanes of local streets to lower speed vehicles including neighborhood electric vehicles, scooters and bicycles.
5. Designating space or facilities in buses and trains for small freight hand trucks and bicycles.
6. Development of transport demand study tools using the Internet to fine-tune and coordinate transport policy and new transportation businesses

These solutions will not provide the same level of spur-of-the-moment convenience as we might find in the recently past era of cheap fossil fuels and widespread personal vehicle ownership. The transport of medium and larger quantities of freight will also require more capital intensive, longer-term solutions. Nor will these short-term solutions provide the same utility of future innovations in electric vehicles and an EV public and quick-charging infrastructure. Some, used to traveling in their own personal space, will

not avail themselves of these stopgap options until they feel more economic pain through still higher gas prices.

The Five Transport Energy Solutions and One Imperative

There are five fundamental options to move into a post-oil, post-natural gas energy world and one imperative:

- **Imperative A: End-Use Energy Efficiency and Conservation.** We will have to invest less in new energy supply if we get more from the energy we use (efficiency) as well as act and plan in a way that recognizes the limited nature of natural resources (conservation). The electron economy scenarios have the greatest potential for end-use energy efficiency. The short-term measures above will also increase efficiency.
- 1. **The Renewable Electron Economy:** electric vehicles, stationary devices, and new electric transport infrastructure powered by electric generators using renewable energy and the associated energy storage challenge.
- 2. **The Nuclear Electron Economy:** electric vehicles, stationary devices, and new electric transport infrastructure powered by electric generators using nuclear energy (with or without fuel reprocessing), with associated security risks, waste and dependence upon fissionable fuel supply.
- 3. **The Coal CCS Electron Economy:** electric vehicles, devices and new electric transport infrastructure powered by electric generators using coal with carbon capture and sequestration, a technological “maybe” dependent upon coal supply.
- 4. **The Coal to Liquid (CTL) Transport Economy:** converting coal to liquids (sometimes via the Fischer-Tropsch process), burned in internal combustion engines leading to climate disaster and resource exhaustion.
- 5. **The Biofuel Transport Economy:** Aggressive expansion of unregulated biofuel production for land transport will almost certainly lead to ecological and social disaster. Biofuels, sustainably produced, especially from wastes, will have a niche in aviation and marine propulsion.

Sub-option for Solutions 1, 2 and 3: The **Hydrogen Economy** is parasitic on the Electron Economies, reducing net usable energy by two-thirds for the purpose of having a compact liquid/gaseous fuel extracted by energy-consuming electrolysis. A Hydrogen Economy therefore requires a 2 to 3 fold increase in the amount of and therefore the capital investment in the required clean electric infrastructure to support renewably produced hydrogen. (There are currently even more expensive renewable ways to extract hydrogen from water using very high concentrations of sunlight that do not use electricity as an intermediary).

Any of these five transport energy supply solutions will be made much more feasible if aggressive end-use efficiency measures are pursued in parallel; therefore the imperative of energy efficiency.

Narrowing the Field

To simplify matters, we can eliminate options “4” and “5” as the costs of climate, ecological, and social disaster outweigh the benefits of a supply of liquid fuel that is not petroleum-based. Analyses that only consider liquid fuels divert the debate, intentionally or unknowingly, from more promising solutions; it is astounding how some commentators can discuss these options as if a continued supply of liquid fuel for transport was somehow worth enormous ecological and human sacrifice.



Lamborghini easily converted this gas guzzling Gallardo to use ethanol yet producing biofuel from food crops for such a car has, in most analyses, shown more negative than positive ecological and economic effects .

Building on early optimism about biofuels from environmentalists, the biofuel lobby, unfortunately, has a great deal of influence in the United States. This is a truly tragic state of affairs in American politics, as many farmers and farm-state politicians have tied their political and economic hopes to this option. Biofuel mandates have pushed up the price of crops and created an incentive to plant and overplant corn as well as other potential biofuel crops. As fuel prices push up food prices, these prices are further elevated by [the transfer of prime farmland from food production to fuel production](#). Without cutting biofuel incentives and mandates, there will be no countervailing influence to conserve the soil or return land to food production. [Talk of cellulosic ethanol](#) or other future innovations in biofuel production function currently as an entering wedge for the current unsustainable variety.

The only savior for biofuels is a rigorous [eco-certification program](#) that excludes the conversion of food crops to fuels, mandates soil and water conservation, and privileges the use of waste streams for fuel. Under such an [international eco-certification program](#), biofuels will have a role as clean marine, aerospace and specialized land transport fuels.

Luckily, the [coal-to-liquids option](#) has few advocates and so far little political support. If however, petroleum prices continue to rise and so-called “skeptics” of global warming continue to be well represented in the US Government, there may be various support schemes for coal-to-liquid that are inserted into legislation. Unlike the biofuels solution, coal to liquids would “work” to move a large group of vehicles for a few decades not unlike our current vehicle fleet, but with enormous climate sacrifice as it represents an increase in carbon emissions over even the current sorry state of affairs.

In the next installment of this series, I will explore which of the three electron economy scenarios will predominate. As each scenario varies only in the manner in which electricity is supplied, i.e. generated, and not used, the below recommendations about how to create a secure post-oil transport system using electricity could apply to all three.

Getting Off Oil: A Three-Pronged Approach

Oil is far from an “evil” but an undervalued resource that has been squandered on tasks that could be much more efficiently achieved through the use of electric drive transport. [Cheap oil](#) has enabled individual and family mobility and autonomy at a low price but these uses now compete with more critical uses of oil in commerce, industry, and agriculture. As we shall see with greater investment in electric transport and infrastructure an equivalent level of mobility in most arenas can be achieved through electric drive transport. Electricity can be generated via a number of different methods, some of which are sustainable and have low or zero emissions.

1. **Electrified Rail and Roadways** – In the last few months, decisions have been made in Washington to spend billions of dollars on bailing out financial institutions that made the wrong bets in the housing and housing securities markets in search of guaranteed or higher than average profits. To get off oil, we will need to make public and private investments in productive assets that



enable transport to be powered by electricity, a much more durable and secure investment. Electrification of railways and key roadways, first in urban centers and then interurban roads, will allow trains, freight and large passenger vehicles to function independently of oil supply. As electric or dual mode locomotives on electrified rights of way are more capable than the majority locomotives in the US, the diesel electrics, fairly inexpensive sets of financial incentives may be sufficient to encourage private railways to electrify. Compared to the other electric options, electrification of rail and local roadways is the most highly developed and highest capacity electric transport option, though the least publicized in an age fixated on new technology. This option has slipped under the radar, as, for instance, Andy Grove, the Intel co-founder and now an advocate of the electrification of transportation, omitted to mention this option in [his recent Washington Post editorial](#) on the subject.

2. **Plug-in Hybrids/Extended Range Electric Vehicles** – The most likely substitutes for small and medium sized vehicles used mostly for local trips but with some longer-distance usage are PHEVs/EREVs such as the upcoming Chevy Volt. In their simplest configuration, these vehicles will be driven by an electric motor that can propel the vehicle for as many as 40 to 60 miles on



GM's Chevy Volt will be one of the first production Plug-In Hybrids which GM is calling an "Extended Range Electric Vehicle" or EREV

stored grid electricity (therefore the "plug-in" part) in a medium-sized battery and can switch seamlessly to using petroleum or other liquid fuels from its conventional fuel tank to run either a generator or small engine to propel the vehicle on longer trips. PHEVs will benefit from new generations of batteries that are more compact than lead acid; however a future revolution in battery and quick

charge technology may narrow the scope of usefulness for PHEVs. Many auto manufacturers are now planning or actually developing PHEV models, including GM and Toyota. PHEVs in wide deployment could reduce petroleum usage by as much as 60 to 70%.

3. **Battery Electric Vehicles/Battery Exchange and Quick Charge**

Infrastructure - A new generation of battery electric vehicles are now being developed with lithium ion batteries that can have ranges of up to 250 miles or can completely recharge within 10 minutes. The [Tesla Roadster](#), a high end sports car with a 225 mile range is just being delivered to customers; Tesla's British competitor with a 160 mile range, the [Lightning GT](#), will recharge in 10 minutes from a 480 volt outlet, making its recharge time approach liquid refueling times. Tesla, Renault-Nissan, and Mitsubishi are all planning



The Introduction of the Tesla Roadster has sparked a revival of interest in electric cars by many major carmakers as well as by start ups.

mid-market or economy electric vehicles with varying ranges all using higher energy-to-weight ratio batteries than lead-acid batteries. Other makers are making short-range vehicles for lower speed city use with the older lead-acid battery technologies. Some are planning to build quick charge or battery swap infrastructure to allow electric vehicles to travel unrestrictedly with short charging or swap stops. As is, battery electrics with even traditional lead-acid batteries can do many important tasks that are now the province of petroleum-powered vehicles.

One of the strengths of this three-pronged approach is that it does not hang its hat on any one technology, distributing risk between three paths. Also by acknowledging the uses of existing battery technology and on-grid transport options, the plan doesn't depend crucially on innovation in batteries or chargers and their manufacture yet also would

take advantage of the opportunities offered by these technologies and their future path of development.

Towards the Post-Oil Society

The tripartite approach allows our society to cut oil demand and dependence substantially within a decade, much more quickly than a sole reliance on electrification of the autonomous vehicle fleet through sales of battery-electric and plug in hybrid vehicles. Combining these vehicles with the already well-proven and easily scalable technology of vehicles that use trolley poles or a pantograph to draw power from the grid while in motion, allows policy makers to take a leadership role when required to supplement the emerging market for personal or corporately owned electric vehicles. Most world leaders with a future orientation recognize a global energy crisis of enormous proportions where electric transport has a crucial role. In an [under-publicized speech](#), British Prime Minister Gordon Brown already sees in electrification of transportation both a business opportunity for the UK and a more general solution to living in a post-oil world.

Advances in battery and ultracapacitor technology and manufacturing technologies are inevitable but the timing of their widespread adoption will substantially lag demand for them. Insistent demands by concerned consumers that Tesla Motors or another manufacturer create in the next few years a battery electric vehicle that is



The secretive Texas company EESstor is claiming that it will produce a revolutionary electric energy storage device, though it has continued to push out the timeline for commercialization.

priced at the level of gasoline powered economy cars are as of today wishful thinking. Batteries, however, will remain far more advanced and widely available than hydrogen and hydrogen fuel cells. Though hydrogen may have a future role, the focus on hydrogen by policymakers and automakers has functioned as a distraction from electric technology, the clear next generation in powering transport. Unfortunately commercial

interests that a decade ago wanted to delay the emergence of electric transport, held onto hydrogen as the next thing to, seemingly, prolong the era of profitable petroleum powered vehicles.

The tripartite strategy allows policy makers to respond more immediately to the demand for oil alternatives by implementing programs that build out grid-powered transportation infrastructure for freight and passenger traffic using “off the shelf” technologies. Policymakers can create incentive packages, issue bonds or levy taxes for the necessary work to keep America moving. Incentives for private companies to invest in electric transport infrastructure can be designed. Beyond its easy scalability requiring few to no technical advances, powering vehicles directly from the grid is highly efficient because power is used directly after generation rather than diminished a fraction through charging and discharging a battery. Using that extra fraction of power for the convenience of storage is well worth it in many contexts but is not necessary for all transport tasks.

Building Electrified Rights of Way

There are now a number of plans emerging on a national, continental and local level to electrify transportation in part. Alan Drake, a contributor to a number of energy and transport websites, has devised [a plan to electrify 36,000 miles of vital freight](#)



Most of America's rail freight is moved by diesel locomotives on non-electrified tracks; with an electrified train system the energy of trains braking could be captured for use by other trains.

[railways](#) in the US and increase the speed of rail freight; higher speed freight allows an easier commingling of freight and passenger traffic on the rails. A [high speed \(electric\) passenger rail line](#) is now being proposed in California to link San Diego and Los Angeles with San Francisco and Sacramento. Public transit advocates have created [visions of how various cities](#) could be transformed with expanded subway or light rail networks, many of which unfortunately require larger per mile investments than simply electrifying existing rails and roadways.

Building of new heavy and lighter rail infrastructure is inevitable but a rapid start to electrification will work with existing rights of way, tracks and roadways. As an exercise, imagine your own local area or, as the [America 2050 plan](#) calls it your larger “megaregion” and visualize where are the highest traffic areas where we could rapidly transfer people and freight from petroleum dependent to electric transport.

An Example: Moving the Northern California Megaregion off of Oil



The [Northern California megaregion](#), in which I live, extends over a huge square of land centered on one side on San Francisco, San Jose and Oakland, approximately ~~250~~ 180 miles per side extending into northern Nevada. The size of this region and the sprawl within it has been enabled by cheap petroleum transport energy despite its foundations in the pre-oil era. On the other hand, Northern California is better prepared than many areas of the Western and Midwestern US to transition to an electricity-based transport system because of existing investments in concentrated freight and passenger transport and some denser core and corridor areas of residence and business. The transition will be more challenging for the “Arizona Sun Corridor”, the “Piedmont Atlantic” and the “Florida” megaregions with their still greater sprawl and dispersion of economic activity.

An inventory of existing electric transport assets in the Northern California megaregion yields the following:

1. the highly successful regional BART (Bay Area Rapid Transit) system, a 3rd-rail driven commuter rail system for which there have been several expansion plans, that are now again made more likely.
2. Three light rail systems in the City of San Francisco, in the City of Sacramento and in the Santa Clara Valley around San Jose.
3. A trolleybus system in the city of San Francisco
4. The venerable San Francisco cable car

These electric transport assets are largely focused at the traditional center of the area San Francisco and are currently designed for passengers and their hand-carried freight. There are however multiple existing non-electrified rail assets in the region for passengers and freight running on freight companies rights of way. These include:

- A. the Caltrain commuter train on the Union Pacific right of way from San Francisco to San Jose and Gilroy
- B. the Capitol Corridor regional trains from Oakland to Sacramento
- C. the ACE train from San Jose to Stockton
- D. Amtrak service linking major centers in the megaregion as well as tying the megaregion to the Southern California and Cascadia megaregions to the north and south.
- E. Freight rail service on the many active railways on both major trunk and also spur lines throughout the region serving industrial and commercial customers.

Electrifying many of these existing routes would further insulate Northern California from dependence upon oil markets. In addition, the region's [Metropolitan Transportation Commission's rail plan](#), announced in 2007, recommends track expansion in addition to that needed by the statewide High Speed Rail proposal. In this plan are efforts to separate out where possible freight and passenger rail to allow each to proceed on its own most efficient schedule. Grade separating rail in densely populated areas is an additional expense that with higher traffic becomes an enormous boost in the quality of life and quality of rail service. While as of last year these recommendations may have seemed like pie in the sky to some, events in the oil markets have made such efforts an ever higher priority.

Less expensive per mile and more rapidly deployed are electrified roadway systems,



While the wealthy and tech-friendly Santa Clara Valley around San Jose will probably lead the nation in the adoption of private electric cars, building 5 or 6 new electrified rights of way for trolleybus or light rail will insulate the operations of the Valley's public transit authority from the oil markets.

now used with trolleybuses but capable of accommodating dual mode electric trucks outfitted with [trolley poles](#) or [pantographs](#). Focusing on passenger traffic, the Northern California megaregion can supplement the railed systems of travel by building at least one electrified lane for trolleybus traffic on major thoroughfares, connecting with rail transport resources. A listing of these routes for the Northern California megaregion would extend perhaps to 50 major street routes of 10 to 30 miles in length and would supplement existing rail infrastructure. These trolleybus routes can either be operated as Bus Rapid Transit in a segregated lane or can commingle with other traffic, part of the flexible appeal of trolleybuses. In addition trolleybuses can operate in residential neighborhoods in the evening and at night without disturbing residents. Almost any bus route could be electrified, though it makes sense to start with the highest traffic routes.

Once any strategy of electrification is recognized as the primary means of powering ground transport, blue ribbon panels of technical, financial and transport analysts can be convened to determine what mix of rail and roadway electrification systems might best

serve to fulfill our current and anticipated future transport needs. One of the priorities of the next Administration ought to be a study of long-distance roadway electrification versus the building out of electrified railway networks inclusive of the expense of improvement of existing railbeds and building new sets of parallel tracks in high traffic areas. Another factor involved in these studies would be the anticipated rate of improvement in mobile energy storage technologies and their manufacture.



PRT advocates believe that people will prefer traveling in private pods routed automatically to their selected destination station on the PRT network

Another electrified alternative is [Personal Rapid Transit](#) or PRT. Still an emerging concept, PRT may use either electrified rights of way or batteries in an automated system of electric “taxis” on guideways. A large PRT system would be unthinkable without advanced information technology and highly reliable automated controls. PRT advocates claim an overall lower environmental impact for their technology over traditional mass transit. PRT critics believe that no PRT system will be able to handle rush hour traffic volumes. The first true PRT system is being built for use at London’s Heathrow airport.

The grouping of shared and rent-able forms of transport around the main transport arteries and stations will further increase the utility and efficiency of the transport system. In France, there are [free shared bicycle services](#) clustered around transport hubs (Velib) and there are also proposals to introduce [a shared electric car service](#) with similar depots scattered around French cities. Van pool and ride-sharing services can grow based on determining where are the centers of transport demand and need.

Electrification of high traffic rights of way is one of the top priorities for both national security and energy security. Alan Drake, in focusing on the already-profitable freight business and rights of way, proposes that minimal federal incentives can stimulate large private investment in electrifying tracks owned by the large railway companies. Publicly owned rails or roadways would require debt financing or budgeting for construction directly from tax revenues for local, state or federal governments.

Promoting Battery and Plug-In Hybrid Electric Vehicles

Governments can play a key role in promoting electric vehicles by buying electric vehicles en masse and helping develop battery electric and plug-in hybrid electric fleets and fleet systems. With current technology, battery electric trucks could already function as postal delivery trucks. Beyond the gasoline hybrid, government service vehicles should be mandated to be electric or PHEV/EREVs with few exceptions. As is proposed in a recent bill in Congress, government can offer tax incentives or rebates to individuals and corporations for buying individual or fleets of electric vehicles. Government can also provide the test bed for developing quick-charge and battery swap systems, especially with fleet vehicles.

Public trickle charge locations at 110/220 volts, quick-charge stations at 480volts and battery exchange infrastructure are another area where local, state and national policy can make a difference. The standardization of public charge plugs, for instance, will allow electric vehicle manufacturers to make vehicles with a higher value to the end consumer, by allowing any vehicle to charge at any public charging station. Government and industry may also need to standardize the battery pack-to-vehicle interface to allow interoperability between more battery packs and more electric vehicles with battery pack exchange capability. Low-interest loans may also enable electric utilities and property owners to install an electric account-linked or pay-per-charge vehicle charging infrastructure of the near future in multifamily dwellings and paid parking structures.

Aviation, Marine and Special Use Fuels

The energy density (the energy content to weight ratio) and energy storage capacity of liquid hydrocarbons will remain for the foreseeable future vital for ships, aviation, remote environments and applications where the substantial heat byproduct of an internal combustion engine is desirable. In these contexts, petroleum products will continue to be dominant until we have developed ways to produce bio- or synthetic fuels that do not substantially interrupt food supplies, exhaust water supplies, or endanger the fertility of soils. Luckily, our use of petroleum as a transport fuel is driven five to one by on-land use, so we will reduce our petroleum demand and our greenhouse gas emissions by transitioning to the Renewable Electron Economy as rapidly as possible.

Concentrated and Smarter Settlement Patterns



"Peak Oilers" predict with steep rises in oil prices that suburbia will depopulate and collapse.

Those who have long predicted a rapid escalation in oil prices with severe social and economic effects, when and if they turn to advocating solutions, suggest that ultimately a post-oil society will have a stronger community focus than the anomie of suburban and widely dispersed rural settlements. James Howard Kunstler, who envisions [the collapse of suburbia](#) after a catastrophic rise in oil prices, advocates for what might be called a new urbanism or smart growth, where people live in more tightly concentrated but humanely designed cities and towns.

There is however a [contradictory current within the same group](#) which suggests that people will need to become more self-reliant, growing their own food, preparing to become more self-sufficient autonomous units that do not require petroleum-based transportation to live. Such a current would suggest that people would use land in a more distributed manner, allowing for larger garden plots around living spaces perhaps leading to an new survivalist agrarianism.

The two contrasting scenarios proposed are based on two different notions of what is ultimately a more resource and energy efficient way to live: more concentrated settlement is built around more efficient consumption while somewhat more distributed settlement suggests that production and consumption should co-exist in the same space. It is unknown the degree to which one or the other of these visions will predominate in the near and medium-term futures.

The tripartite approach to electrifying transport concentrates some transport tasks along main electrified rights of way while leaving open the degree to which people and the machines they operate can range off of the grid using batteries or liquid fuels. Demand for transport and goods traffic along these main corridors will remain high even in times of crisis or in a theoretically more dispersed population of part-time farmers. Neither more efficient consumption nor a commingling of consumption and production is necessarily favored. I have explored in [one installment of my series on the Renewable Electron Economy](#) the possibility for farmers to use electricity to do many farming tasks that are now petroleum dependent.

In any case, it is premature to predict massive internal migrations and collapse of whole economies as oil prices continue to climb, especially if these three paths towards electrifying land transportation are pursued aggressively and effectively by government and industry in the next few years. Additionally short-term measures to increase the efficiency of our transport system as outlined above can be implemented rapidly by a combination of public agencies and private companies that recognize the opportunity to provide people with more effective and more efficient transport choices even in an era of more expensive energy.

2. Supplying Clean Energy

(originally published August 20, 2008)

In the first part of this mini-series for policymakers, I addressed the marquee issue in energy currently, finding a replacement for limited, expensive and polluting petroleum; I concluded that a three-pronged approach based on electric traction in transportation would go the furthest in reducing our dependence on petroleum. But that electricity would need to be generated in a timely manner... or energy would need to be stored or accessible in a ready form. In this next installment I am going “upstream” to look at what our choices are in a post-oil, post-carbon world to generate electricity in a clean, useful and timely manner.

Why is Electricity the Energy Carrier of Choice?



Our already substantial investment in an electric infrastructure over a period of 120 years in industrial countries, makes the transition to a electricity based energy easier as "sunk costs" can be utilized for the future.

There are sound physical reasons why, in the first installment of this series, the three main contenders for the energy supply for transport turn out to be the three electron economies, the Renewable, the Nuclear and the Coal CCS. We have determined there that electric drive vehicles either attached to the grid or powered by some version of a battery can do most of the on-land transport tasks that are now dependent on oil supplies. There are other reasons why electricity is valuable for driving stationary machinery as well which we will go into in the final installment of this series.

Why then is electricity preferable to biofuels, hydrogen and coal to liquids? In addition to zero emissions at end use, electricity has benefits in efficiency and availability in almost all stages of its production, transmission, and consumption. Electric generators can be built to use a wide variety of types of energy (heat, light, mechanical energy) to

create the highly usable and flexible energy carrier, electric current. In other words, electricity is the ultimate in “flex-fuel”. All renewable energies (wind, sun, geothermal heat, wave, tidal, biomass, natural chemical and thermal gradients) can be converted into electricity with existing technologies. In addition, while we must shift the way we generate electricity in most instances, this is not a full-scale rebuilding of our energy system but a modification of existing infrastructure, so in the end, less expensive.

Existing electrical generation technologies convert a fairly large amount of the primary energy that they receive into electric energy. Current solar panels, for instance, can convert anywhere from 10 to 40% of the energy of the sun into electricity depending on the technology; by contrast plants convert at most 1% of the energy of the sun into biomass, an energy harvest that is further reduced if that biomass is converted into a liquid biofuel rather than burned in a biomass electric generation facility.



Electric motors are so compact that this electric sports car, has a 120kw (163 horsepower) electric motor in each of the hubs of its wheels, each of which weighs 55 lbs; an equivalent internal combustion engine would be several times larger and heavier as well as much more inefficient.

Additionally, electric motors, because of the physics of the electromagnetic force, are incredibly efficient at generating torque, the useful product of engines and motors. An electric motor of medium or larger size (90-95% efficient) requires somewhere between one third and one-quarter the amount of energy to do the same work as an internal combustion engine(20-30% efficient): they therefore generate 3 to 4 times more torque per unit energy put into them, than all but the largest and most efficient house-sized diesel ship engines (50% efficient).

Electricity also can be used for a huge variety of functions for the end user: generating mechanical movement, heat, light and sound. So electricity is both flex-fuel and flex-use. It is no wonder that, even with no consideration for the current energy and climate concerns, more and more devices have been designed with more electronic components to increase their functionality, including petroleum powered automobiles (electronic fuel injection, stability control, drive by wire, etc.).

Electricity's weakness has been that electrical energy storage is bulky and heavy in comparison to the portable liquid fuels to which it is often compared. Batteries and ultracapacitors are still relatively large and expensive compared to a liquid fuel tank and the hydrocarbons that are pumped into it. As the drawbacks of fossil fuels are starting to be more widely recognized, the positive attributes of alternatives are once again being recognized. Also, substantial investment is once again flowing into resolving this one final hitch in electricity's otherwise near-ideal attributes and the technological development curve promises rapid advances.

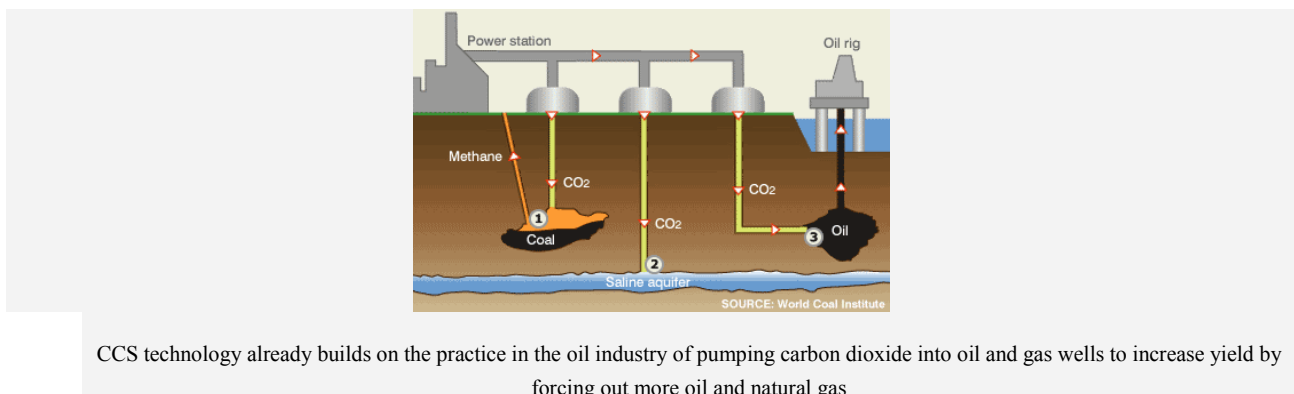
In the distant future, we may have other energy carriers with more favorable characteristics but for the foreseeable future it makes the most sense to build on the advantages of electricity.

A Choice of Primary Energies: What is the Clean Energy of Tomorrow?

Usable electricity just doesn't appear but is generated from a pre-existing or primary energy; one of the great decisions of the 21st Century will be how we choose to generate electricity. We have established that there are under consideration three main carbon-reduced or carbon neutral "clean" primary energies for electricity: renewable energy, nuclear energy, and coal with carbon sequestration. While electricity itself is "flex-fuel" meaning that any and all of these methods can be used to generate electricity, we will need to arrive at a differentiation of, if not a prioritization of, which methods are going to be the most sustainable and ultimately the main driver of the new electron economy, post-coal and post-oil. To guide policy and investment, we can create a "loading order" for these resources, though a multi-track approach is also probable if not desirable.

Third Place: the Coal CCS Electron Economy

Is coal with carbon capture and storage (CCS) the primary energy source for the Electron Economy? Of the



three alternatives, coal generation with CCS is the least promising as it has some major strikes against. However it does have some advantages as well.

Pro:

- Taps into a still vast energy store (coal deposits) so can be called upon when needed independent of weather conditions and in response to electric demand.
- Provides jobs and revenue for existing industries and communities (coal mining and coal transport)

Con:

- Uses an unsustainable fuel – coal will run out
- Coal mining is often very destructive to the landscape and to coal miners.
- Mass carbon dioxide release from underground is considered unlikely but potentially lethal for people and wildlife as well as defeating the purpose of CCS.
- CCS may not reduce or eliminate the other pollutants associated with coal combustion including mercury emissions, SO_x and NO_x.
- There are still no functioning plants/it is an experimental technology
- CCS plants will be much more expensive than existing coal plants, removing one of the prime selling points of coal, i.e. that it is cheap
- CCS or "clean coal" has been used as a public relations "cover" to justify the building of new coal generating plants without adding the "optional" CCS facilities.

Coal with CCS may have a role in a transition to a more sustainable energy system but it is by design a stop-gap solution.

Second Place: the Nuclear Electron Economy



In the light of concerns about climate change, some environmentalists as well as those within the nuclear industry, have emphasized nuclear energy's carbon neutrality; advocating it as the solution to climate change.

In light of concerns about climate change, the role of nuclear power in a future or transitional energy system has been re-evaluated. Worries about nuclear plant safety, nuclear weapons proliferation, and nuclear waste are being balanced against the fact that

nuclear plants during their operation do not emit carbon dioxide into the atmosphere. Unlike coal-fired generation, nuclear power technologies, especially if we consider prototype reactors, vary greatly and massive government investment has gone into researching a wide variety of reactor designs; however one type, the pressurized light water reactor, still predominates in commercial nuclear plants. I will treat nuclear as two concepts then, existing nuclear and potential nuclear designs. I am considering potential future nuclear designs at all because the physics and history shows at least the potential for a high energy yield, though at a price worth assessing.

A. Existing Nuclear (Pressurized Light Water Reactors)

Most existing nuclear reactors use regular (light) water as both a coolant and what's called a neutron moderator. They depend on an enrichment process by which fuel pellets are formed with a higher concentration of the fissionable isotope Uranium 235 rather than the much more common and stable U238 isotope. These reactors pros and cons are as follows:

Pro:

- Carbon neutral under operation
- Established technology with track record of producing electricity with few safety incidents
- Produce power in the same profile as most coal generation plants (a constant baseload); can be used as a coal substitute
- Remaining Uranium 235 supply functions as an energy store that can be tapped into at will
- Nuclear power enables power production in areas with poor natural and renewable resources
- Nuclear fuel is compact and highly energy dense

Con:

- Produces large amounts of highly radioactive nuclear waste that will need to be stored for millenia in isolation from the biosphere.
- The uranium enrichment process can also produce higher concentrations of U235 suitable for nuclear weapons.
- The Chernobyl reactors were pressurized light water reactors; accidents and assaults on these plants have a chance of resulting in catastrophic releases of radioactive materials
- Naturally occurring, economically extractable U235 will run out sometime in the latter half of the 21st century, especially if new nuclear plants are built out aggressively.

- Constructing nuclear power stations takes over 5 years making them ineffective in a crucial period of climate change
- Inclusive of insurance costs, which are so high that they must be assumed by governments and therefore taxpayers, nuclear power stations are very expensive

Pressurized light water reactors then are not a particularly promising solution to our energy crisis, especially in the longer term.

B. A Future Fuel-Reprocessing or Thorium-based Nuclear Power System



In some versions of a future nuclear system, fuel reprocessing facilities like this one would extract fissionable fuel from reactor cores that had been bombarded by neutrons during a reactor's normal operation, creating U235, U233, and Pu239. A future nuclear system would in some ways be more complex than our current one as non-fissionable heavy elements will need to be transformed into fissionable ones before use in power-generating reactor.

Some nuclear power advocates believe that most or all of the drawbacks of the current nuclear power system can be remedied through technological development of a combination of new reactor designs, new ways to process fuel, and the extraction of fissionable fuels (uranium and thorium) from new sources. In sum or as piecemeal solutions these changes are supposed to reduce the toxicity and amount of nuclear waste, increase the amount of fissionable fuel up to several thousand-fold, and reduce the risk of nuclear proliferation. These technologies however do not represent a unified plan but rather a series of technology proposals that build upon past or existing prototype reactor designs and fueling systems that have either been built or speculatively might be built.

One of the objectives of these scenarios is to widen the potential base of nuclear fuels by creating reactors that can turn much more plentiful Uranium 238 or Thorium 232 into a fissionable fuel (Uranium 233 or 235 or Plutonium 239). Others suggest extracting fuel from sea water, which has a small but nevertheless plentiful fraction of uranium isotopes in it. The net effect of these new fuel processing and sourcing proposals is to extend the supply of fissionable fuels to hundreds if not thousands of years into the future. Still others suggest reactor designs that will not allow weapons-grade uranium and plutonium to be isolated. Some tactics involve using discarded nuclear wastes as fuels as well as producing a much smaller radioactive waste product with a half-life in the hundreds of years rather than in the tens of thousands of years.

Out of concern for the urgency of the climate crisis, I depart from the orthodoxy of some advocates of renewable energy by agreeing that it is desirable to do research into reactor designs that at least reduce the toxicity of current nuclear waste and create a safer nuclear fuel cycle. While it is difficult to pin down what the pros and cons of this ideal future nuclear energy system might be, the following are some advantages and disadvantages of foreseeable nuclear power systems:

Opportunities:

- Carbon neutral or negative (in certain conditions) under operation
- A future nuclear system might be able to reduce our current nuclear waste problem
- Fuel is compact and easily transportable
- Nuclear energy that can make U238 or thorium fissionable can tap into a very large store of fuel, and can therefore be used at will for many years to come; according to advocates for thousands of years.
- Like conventional nuclear power, could produce baseload power, substituting for coal generation
- Removing proliferation risks could make cleaner power available to more countries
- Safer reactors are desirable if nuclear energy is to continue to be part of our energy mix
- Nuclear power enables power production in areas with poor natural and renewable resources

Risks and Disadvantages

- The described future nuclear system is more than a decade and perhaps decades away. Climate change is upon us now.
- All nuclear power irreversibly transforms its fuel into less energetic fuels; even after thousands of years it will run out
- The promised benefits may not materialize.
- The complexity of these proposed systems is very high, making oversight difficult and increasing the potential for unforeseen difficulties and consequences
- As yet uncharted safety issues will emerge with new radioactive fuels or coolants like liquid fluorine.
- Developing these systems would be a major expense drawing on government research funds diverted from less elaborate technological systems like renewable energy and energy storage.
- Existing fuel reprocessing systems have proliferation risks attached; they isolate plutonium.

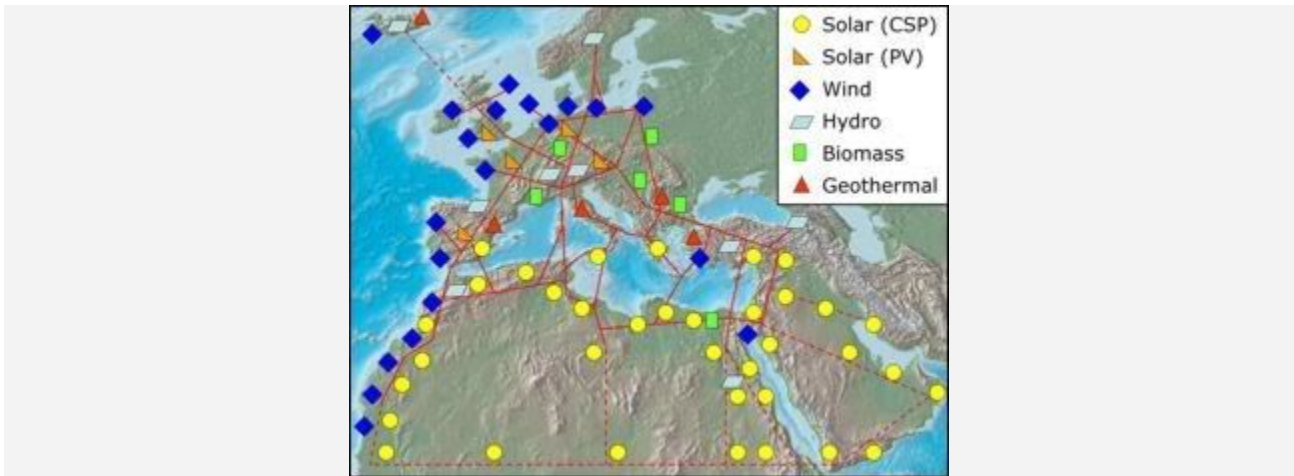
- The compact power of fissionable elements may have more appropriate uses in some future technology (spaceships?) other than power generation for daily use.

The Nuclear Electron Economy, be it in its conventional form or a potentially improved future form, is a runner-up to the Renewable Electron Economy largely because it is not ultimately sustainable, carries with it large technological and safety risks, and its deployment as a substitute for fossil generation is many years away.

First Place: the Renewable Electron Economy

As you might expect from an analyst who has written about the Renewable Electron Economy, I believe that the mainstay of our future energy system will be electric generators powered by renewable energy. However, I hope to show here that this choice has a basis largely in economic, scientific and technological reality rather than my personal prejudice or some of the social utopian ideals to which renewable energy has been attached.

Though I am for a comprehensive push to develop and deploy all types of renewable electric generators, constructing a Renewable Electron Economy, where renewable energy does the heavy lifting, will require a focus on specific strengths and weaknesses of renewable energy. Advocates for renewable energy have tended to either cluster into an “anything goes” ecumenical approach or focus on renewable energy as a self-generation option for households and business. Some have championed renewable energy as a means to even dismantle a widely interconnected grid through each power user autonomously producing their own power. Why one would want to dismantle the grid seems to be a matter of personal preference or fixed ideas about how society should function rather than a reflection on the electric grid’s usefulness.



The DESERTEC concept sees a linkage between renewable generators throughout Europe, North Africa and the Middle East to balance renewable energy flows and, in addition, enable water desalinization in desert areas. In the US and North America, a similar concept does not need to traverse so many international boundaries.

The approach to renewable energy I favor emphasizes the power of widely cross-linked generators to tap into the strengths of renewable energy and address its weaknesses in an energy economy where residential, commercial and governmental users are actually depending on renewable electricity to provide them with the energy they need. Solar panels on rooftops or small windmills alone will not, with current generation and storage technology, be sufficient to substitute for the day and night, always-on power of our current grid. Combining large and small generators including solar thermal with storage, hydroelectric, pumped storage, biomass power plants, as well as more familiar wind and photovoltaic generators can reproduce under most conditions, the reliable power of the grid.

The most promising technology in this area is not simply horizontally networked generators but a well-orchestrated mini-grid regulation system that can be called a “renewable combination power plant”. The renewable combination power plant joins discrete renewable generators together to deliver power exactly as it is needed by grid users, just as is done today with conventional power plants. In contrast, isolated renewable generators without storage produce power according to the availability of their primary renewable energy. The combination power plant operators respond to signals from the power grid operators about when and how much power is needed. A renewable combination power plant requires, as at least some components, clean storage technologies or dispatchable renewable resources like biomass power plants, hydroelectric, pumped storage, and solar thermal with storage. These controllable resources are then extended by wind, wave, tidal, geothermal or photovoltaic solar power which produce power whenever they have incoming renewable energy.



The Solar Two demonstration power plant, built by the US Department of Energy, generated power for seven days and nights continuously using only solar power, which was stored for night time use as heat.

Even with current technology, however, there is one renewable technology that can do a majority of the work of current fossil generators, solar thermal electric with thermal storage also called CSP (concentrating solar power) with storage. Sited in desert or semi-arid areas, solar thermal electric uses mirrors to focus direct sunlight on a thermal fluid, like water, oil or molten salt that is used to make steam to generate electric or stored as heat in heat storage for later, similar use. The relative efficiency and low cost of thermal energy storage, the relative vastness of the world's major deserts, and the consistency of the desert sun are the strengths of CSP with storage. Solar thermal with 16 + hours storage or solar baseload can substitute for coal generation during much of the year and about 1% of the area of the world's deserts could generate all the power that the world currently uses.

The use of CSP to serve a majority of the world's power customers requires the building of long distance power lines mostly likely using high voltage DC technology that can theoretically transmit power for 4000 miles with about 20-25% losses. There are a number of concepts now being discussed including DESERTEC which links Europe with North Africa and the Middle East, as well as a concept I promote, the Solar Southwest Initiative, that foresees linking the Southwestern and Sonoran desert with power demand centers across North America. In the end, local resources and distant renewable resources will combine to produce a complex but more robust and reliable clean power grid.

Added to the options of the combination power plant and solar thermal with storage are several other technologies that will significantly contribute to the Renewable Electron Economy: small and medium hydroelectric, deep geothermal, as well as better publicized wind and solar photovoltaic. Developing these renewable power resources in some of the more favorable areas will involve the building of some new electric transmission, which advocates of small-scale renewable energy have often opposed (or opponents of transmission have often advocated small-scale renewables as if they substituted for large-scale renewables). The balancing of renewable energy flows across space and time to meet current demand for power requires transmission that links supply and demand.

Currently wind energy is one of the least expensive renewable energy sources and in the future solar photovoltaic (the flat panel technology seen on roofs and emergency call boxes) will probably be as inexpensive as wind. While both of these technologies are currently the "marquee" renewable technologies, alone they will not be able to shut down fossil power plants. Until electric energy storage will be plentiful and cheap these technologies will function best in the context of combination power plants

As described here, the Renewable Electron Economy has the following advantages and disadvantages:

Pro:

- Carbon neutral or negative (in certain conditions) under operation
- Primary energy (fuel) is free
- Generators can be scaled from very small to very large; investment amounts can range from a few hundred dollars to several billion dollars.
- Primary energy is virtually endless
- With the exception of biomass and certain geothermal wells, have no non carbon emissions
- Mature or rapidly maturing technologies in most categories of renewable generator.
- Deployable within a few months to a few years for most technologies (within critical period to reverse emissions trends)
- Dependent upon a diversity of primary energies

Con:

- Many renewable energies are periodic or intermittent
- Renewable energies occur naturally as energy flows rather than energy stores or stocks (with the exception of biomass); an all-renewable grid needs to build up and carefully manage stored energy.
- Overreliance on biomass, the primary natural energy storage medium, may tax soil and the biosphere.
- The reduction in solar energy around the winter solstice may present challenges for a solar-dominant all-renewable grid especially during times of low wind.
- Catastrophic reductions of solar radiation (i.e. volcanic eruptions) can reduce the main energy in-flows; solar radiation is important to both solar and wind generators

The Renewable Electron Economy organized around combination renewable power plants and solar thermal power with thermal storage will minimize or eliminate most of the drawbacks of renewable energy. The emergence of scalable deep geothermal power or EGS, will address the latter two, more difficult but lower-frequency challenges facing an all-renewable grid.

Al Gore's Call: 100% Renewables in 10 years

Al Gore has inspired many of us with his call for a 100% renewable grid to be built in 10 years and, in the area of energy policy, we are in dire need of inspiration. On the other hand, considerations of reality, scientific and financial, need to work together with vision and inspiration to construct a functioning clean energy system in the real world. In my next installment I will take a look at the policy and economic drivers for creating

a Renewable Electron Economy that will serve our energy needs and make the survival of a human-friendly biosphere more likely.

Economic and Policy Drivers for Clean Energy and Transport Infrastructure

(originally published September 9, 2008)

In the first two parts of this summary series for policy makers, we have established that electric driven transport can fairly rapidly substitute for petroleum in most ground transport applications and that renewable electric generators will be the most quickly deployable and functional of the available energy alternatives. Building a renewable electron economy is the key frontline approach we have to creating an energy system that does not depend on exhaustible resources or emit fossil carbon into the atmosphere. However, there are challenges and barriers to overcome in order to move quickly towards the clean energy economy of the near future as we have not yet seen a strong, spontaneous market for such a solution emerge on its own. This is where policy and the structure of our financing system for infrastructure and energy are key.

Is Al Gore's Goal of 100% Clean Electricity in 10 years Possible?



The We Campaign's media blitz, including multiple web and TV ads, has in 2008 given high visibility to the idea that all of our energy can come from clean sources.

Al Gore and the Alliance for Climate Protection have issued a call for us to "Repower America", generating 100% of our electricity from clean sources within 10 years. Gore's call has sometimes been reported as 100% renewables but if you read his statements closely, he says "clean" sources; he may be including nuclear and coal CCS in the mix though the examples he usually puts forward are renewable energy alternatives. I support the efforts of the We Campaign, yet I believe leaders of the climate protection movement need to level with the American people about what will be involved in building this much energy and transport infrastructure that rapidly. Ambitious goals are

good but it would be still better, to set into motion financial and policy mechanisms that will ensure a rapid start to this project. Involved in those decisions are not only the purity of noble intentions but also tough decisions and some sacrifice.

Renewables: Virtuous Side Salad or Energy Main Course?

Much renewable energy policy has incentivized the building of renewables as a virtuous "side salad" for a basically functional but dirty electric generation system, our main energy "meal". In fact, energy industry insiders including Dick Cheney have misrecognized renewable energy, the first power source for the first electric grid, as simply an ineffectual display of personal virtue. Despite the current Administration's lamentable record in moving America toward our energy future, somewhat more forward-looking state-level policies have actually tended to reinforce the view of renewable energy as a personal statement or an act of corporate social responsibility for utilities or their large-scale customers. These state-level policies have often focused on rooftop photovoltaics or delivering a small fraction of wholesale energy through renewable generators, the Renewable Portfolio Standard policies or RPS.

While these, often token, policies have helped keep the renewable energy industry on life support, policies like the RPS, will not by themselves, drive the building of a largely renewable or all-renewable grid. In an era where we are now targeting closing down fossil generators and replacing them with renewable generators, policy instruments will have to change as the focus switches to building an integrated Renewable Electron Economy.

Renewables and the Cheap Energy Contract



In May 2008, after the Indonesian government cut fuel subsidies, raising the price of gas by 30%, rioting and protests broke out in the streets. The government was forced to choose between fiscal solvency and popular support as the price of crude oil rose in 2008.

Recent political maneuvering around the issue of offshore (and Alaskan) drilling has highlighted the continuing strength of what I have called "the Cheap Energy Contract", a social contract particularly strong in North America in which energy costs are supposed to contribute only negligibly to family and corporate budgets. A politician who does not throw themselves full-force into rhetoric or actions designed to depress the current price of energy at the pump or electric meter today risks the ire of voters whose focus has narrowed to present day pocketbook issues.

More than just being addicted to oil, Americans are addicted to cheap energy. Cheap energy today is supposed to be a cornerstone of our democracy, even though maintaining its low cost at this moment in time is extremely costly for the environment and for the future price of energy; the focus on low energy costs keeps us hostage to exhaustible and polluting fossil sources. We are seeing versions of the Cheap Energy Contract emerge in the developing world (India, Indonesia, and China) in the form of oil subsidies, subsidies which are becoming increasingly difficult for these governments to afford as the price of oil continues to climb.



On the evening before the Indonesian fuel subsidies were lifted, motorists waited to fill up at the lower, subsidized price for the last time.

Artificially cheap energy keeps energy alternatives out of the market until there are major supply disruptions or a continuing pattern of punitively sharp price spikes in existing dominant energy supplies; worldwide 85% of supplied energy originates from fossil sources, mostly coal, natural gas, and petroleum. Electricity from renewable generators is still in most cases too expensive for those who adhere to the dictates of the Cheap Energy Contract, and is therefore dismissed by commentators who insist on a price for clean energy that matches that of current dirtier energy supplies. RPS laws, for

instance, usually mandate that utilities bring the requisite percentage of renewable generators online at “least cost” without regard for power quality and therefore the ultimate usefulness of the renewable generator.

Even advocates of clean energy are swept up in the vortex of assumptions surrounding the Cheap Energy Contract. For instance, climate and energy analyst Joe Romm, with whom I agree on many points, often criticizes nuclear, fossil or other energy sources he opposes by using their (high) cost as a decisive argument against their continued use or future deployment. When he does this, in my opinion, he reinforces a framework that emphasizes cheap energy now, an argument that easily can blow back in his face if he argues FOR most renewable energy sources to be deployed today at their current price levels.

So How Much Do Renewables Cost?

One of the attractions of renewable energy is that for most renewable generators, except biomass power plants, the cost of the fuel is free. However even more so than with a conventional power plant, much of the expense of a renewable generator is concentrated at the beginning of the power plant's life. The cost of electricity is the sum of the initial, fixed capital costs for building a generator, variable costs of maintenance and fuel, any profit or return on investment, and finance costs divided by the usable energy produced over the lifetime of the generator. Currently, renewable generators range in cost from expensive (small installations of rooftop or building integrated photovoltaics) to competitive (large onshore wind turbines at windy locations). For renewable energy, the strength of the renewable resources at a given location has a major effect on the price of energy, as the capital cost is approximately the same for areas with higher and lower strength resources, yet the same equipment will produce much more energy in a more favorable location (for wind in particular).



Pictured here in California's Tehachapi Pass are two generations and sizes of wind turbine: a larger more efficient turbine that is better positioned to tap into stronger winds higher off the ground and many smaller older turbines. Installations of turbines of the newer type in an area like the Tehachapis would produce energy at a significantly lower cost per kilowatt-hour.

Furthermore, most natural renewable energy flows are relatively diffuse; they have a lower "power density" than the energy flow that is emitted by a coal or gas fire or a nuclear chain reaction (exceptions are some powerful rivers, tidal flows, and hot geothermal wells). This means that the capture devices for renewable energy flows must, in most cases, be physically larger to take in the same amount of energy as a coal or gas power plant well-supplied with fuel. The large size of the generator means the production and installation of more concrete, steel, silicon, and/or glass as an initial investment. To the chagrin of some renewable energy advocates, also a larger size of the installation and the generators involved usually produces a significantly lower cost per unit energy relative to a small installation of the same technology, contradicting the "small is beautiful" philosophy that has become an unquestioned mantra in many quarters.

Despite the initial investment hurdle and current uphill financial battle, setting up a renewable generator in a favorable location pays off in the long term. Using the measure Energy Returned on Energy Invested (ERoEI) that measures the net energy yielded based on the energy input into a process, renewable generators using current technologies return from 20 to 50 times the energy required to manufacture, construct, and maintain them. This number will tend to go up as the renewable industry becomes more efficient: early solar panels in the 1970's may have had an ERoEI of less than one (negative net energy) but now the roll-printed solar cells of the innovative company NanoSolar may return over 150 times the energy required to make them, paying back the energy used to make them in approximately a month. The latter amount is superior to the ERoEI of an oil gusher of high quality crude from a large oilfield; analysts currently believe the ERoEI of our current more "difficult" oil is around 5 and is decreasing as oil becomes more difficult to extract and is of lower quality.



The 1910-1911 Lakeview oil gusher in Bakersfield, California. Oil gushers had a high EROEI as a high-energy fuel was delivered to the surface by natural underground pressure. Early renewables could not match this energy yield for the energy expended. Innovations in the manufacture of renewable generators over a period of decades have now led to significantly higher EROEI for many renewables than for contemporary, more difficult oil extraction.

In current dollar terms, building new renewable generators is for the most part not yet competitive as the future rise in cost of fossil fuels is usually discounted, while the environmental, energy security and EROEI advantages of renewable generators are not priced into the energy they generate. Energy from existing renewable generators that have already been paid for (older hydroelectric dams or geothermal wells) produce energy at a very low cost. Among new generators, large on-shore wind generators in windy areas produce energy at 6 to 8 cents/kWh which is competitive with new fossil generation. However, the value to the power system of electricity produced from wind, which often does not blow in sync with energy demand, is less than that produced using an energy store, like coal, natural gas, biomass, stored thermal energy of the sun, hydroelectric reservoirs and pumped storage, large batteries and other clean energy storage devices.

Most of the renewable generators and storage devices required to build the renewable electron economy currently produce what might be called “mid-priced energy”, energy that is neither dirt-cheap nor prohibitively expensive. The single generation technology that is the most rapidly deployable that can replace the services of coal and natural gas power plants is solar thermal with storage, which can produce power for somewhere between \$.15 and \$.20/kWh, inclusive of reasonable profit, in the desert Southwest of the United States. Large-scale photovoltaic arrays can produce energy at around \$.25/kWh when the sun is shining in the Southwest. We will expect these prices to go down substantially, once we have created consistent demand for these technologies. Small installations of photovoltaics on rooftops remain relatively expensive, producing

energy at somewhere between \$.45 to \$.60/kWh because design and installation costs are spread over a very few solar panels. Geothermal wells will produce at variable costs from \$.10/kWh to \$.25/kWh for more difficult, lower temperature resources.

In general these more controllable or predictable renewable generators produce electricity from anywhere from a few cents to several tens of cents more than what utilities want to pay per kWh for wholesale generation in current markets. The gap between the market, “buy” rate and the economically feasible “sell” rate for renewable plant developers is then the object of most renewable energy promotion policies throughout the world. Building up these industries will in most cases drive the cost of energy down as economies of scale are achieved and technologies develop.

How Do We Build (Energy) Infrastructure?

The enthusiasm for unregulated markets in the last 30 years of American public policy has obscured how large pieces of infrastructure get built. Unregulated markets, to work according to their ideal, require economic actors to be able to create competing offers which are judged by consumers or buyers according to the total value they represent. Infrastructure by its nature involves building structures so massive that to build competing pieces of infrastructure is considered to be economically inefficient if not socially undesirable (two roads or bridges that “compete” with each other would be an eyesore and end up being much more expensive for society). Power plants inclusive of larger renewable energy installations can be considered on the smaller end of "infrastructure" but are still too massive to build "on spec". Infrastructure then can only get built by large economic actors like governments or corporations opening a bidding process by which manufacturers and construction companies attempt to earn the multi-year contract to build that infrastructure.



Tolls are an ancient but often unpopular means of paying for infrastructure. Toll revenue is usually used for purposes beyond road or bridge maintenance which can breed added resentment among motorists. Tolls, in moderation, are however effective and justified, as

There is however, an abiding interest by both the buyer and the public in general in the quality and durability of that piece of infrastructure, which by its nature is supposed to last from anywhere from 10 to 50 years. So, a bidding process is not simply looking at the lowest total price of the contract but at the quality of components within that total price through an engineering analysis. A formula “cost plus reasonable profit” is used to determine by the buyer and by third party firms whether the bid is realistic and will produce the desired result. Additionally in such a long process there is also an interest in the continuing financial viability of the firm selected, that if it went bankrupt in the middle of construction, would further complicate the process. The “low-balling” of bids is then less attractive than it is in the pure market setting. While there are disadvantages to this formula, it provides a nascent or vital industry with security that pure market pricing does not.

Most of the electrical infrastructure that we have currently was built several decades ago by the utilities, usually large private companies, under government regulation or built directly by the federal government itself. Winning the contracts to build this infrastructure has involved a combination of the offer of appropriate technology and price considerations. Consulting engineering firms and government regulators combine to try to keep bids from being padded too much yet on the other hand to ensure that quality standards are not endangered and the bidding firm will remain viable. This type of cooperation between buyer and seller is not the norm in the ideal “free” market. However, ideal free markets have rarely been involved in building the unique structures that make up most public infrastructure, nor do we have a plausible model for a free unregulated market to be able to do so in the future.

The cost of power is partly derived from the costs of building energy infrastructure plus a reasonable regulated profit; historically the pricing for infrastructure and the resultant power has been arrived at through negotiations between public utilities regulators and power companies. With the vogue for markets extending to all aspects of economic life, legislators have attempted to introduce, post-hoc, market competition to reduce the price of power but these efforts have had mixed if not at times disastrous financial consequences for utilities. While in some places this has reduced the cost of power to consumers for at least a period of time, the costs of building and maintaining infrastructure has not been fully accounted for in the rush to impose market structures on the electricity system. The continuing push towards deregulation, which still has ideological momentum despite bitter experiences in California at the beginning of the decade, does not promote the building of new infrastructure, let alone a new, replacement clean power infrastructure that would reliably produce power. Furthermore,

there are few mechanisms in the current market that would accelerate the retirement of existing fossil plants for new clean energy power plants.

While neither “cost plus reasonable profit” nor unregulated market pricing are ideal, universal pricing mechanisms, there is little in this world that is ideal and universal, especially in the hotly contested area of how to pay for vital commodities and infrastructure.

Non-Transparent or Hidden Renewable Energy Promotion Policies

Tax Credit Policies

One of the ways that the gap between market and the feasible price has been bridged is through the offering of tax benefits to investors in renewable energy plants. Just as the oil and gas industries have enjoyed various tax benefits to encourage investment in drilling, exploration and production facilities, in the last couple decades, investors in renewable generators have enjoyed either production or investment tax credits that contribute about 3 cents to the value of a kilowatt hour of renewably generated electricity for the producer. While these subsidies are set to expire at the end of 2008, most plans for new installations of renewable energy generators are contingent upon their renewal.

Tax credit policies have three drawbacks that make them politically vulnerable: they are largely invisible to the public, they are dependent upon the state of the federal budget and Washington politics, and they apply mostly to large corporate entities rather than small investors. A tax credit is paid via drawing tax revenues from other taxpayers and budgets, not necessarily from tax revenues from other parts of the energy sector. These credits have also been terminated a number of times over their checkered history, putting the renewable energy industry on a roller-coaster. Finally, they are most attractive to large corporate investment vehicles and do not represent an incentive for small and medium investors to get into the renewable energy game.

Tax credits may have a role in promoting reinvestment in existing infrastructure, by, for instance, incentivizing the large railway companies to electrify their rights of way, as suggested by Alan Drake.

Renewable Energy Credits (RECs) or Green Tags

Another method for trying to make up the difference between a wholesale market price for power and the feasible price for renewable energy investment is to sell a green power attribute separately from the power itself as a “green tag”. Also called “Green Power Marketing”, the idea is that companies and organizations can buy these tags to green their power mix, even though they are actually using the mix of power that is available in their area at their facilities. This is the closest one can get to a “free” market in

renewable energy (credits) and those who are enamored of unregulated market mechanisms favor this type of approach.

Studies have found that REC schemes only have a mild stimulative effect and are a relatively expensive means of promoting renewable energy; there are suggestions that the traders of these credits are the prime beneficiaries of an REC system. Furthermore, RECs stimulate mostly large onshore wind farms as green power marketers are only looking for a “green” attribute at the lowest cost; to build the renewable electron economy we will require a more diverse set of renewable generators.

Net Metering

For small renewable generators that operate on the premises of a power consumer, power companies allow the customer to “run their meter backwards” crediting the customer for the full retail cost of the electricity they generate on premises. While this may appear to be simple and fair compensation to the customer/owners of the generator, the (hidden) subsidy for net metering comes from other power users who compensate the power utility for lost profits from the sale of electricity to those self-generating customers. A limitation of net metering is also the loss of any revenue for over-sizing the on-site generator and overproducing clean electricity above and beyond usage on-site.

Transparent Clean Energy Policies

The foregoing finance mechanisms tend to hide the costs of building renewable generators by concealing the actual cost per unit electricity and for the ratepayers or taxpayers as a whole. In an era when so much is hanging on energy policy, it makes more sense to consider policies that do not pull punches when it comes to costs and benefits.

Renewable Energy Payments (REPs)



The Spanish REP program for solar thermal power allowed the European solar thermal electric industry to leapfrog the American industry; despite a lower power solar resource in Spain, the first commercial solar thermal plant with storage in the world is scheduled to

go on-line in Andalusia later this year. The Andasol 1 plant will be able to generate power continuously 7 hours after the sun goes down to supply the evening power usage peak, using stored solar heat in the tanks above.

A more transparent approach to spurring the market for renewable energy technologies are Renewable Energy Payments (REPs) a.k.a Feed-In Tariffs. REPs name and guarantee a feasible price for renewable power from supported technologies under a variety of conditions related to the size and siting of the generator. A successful REP system supports a variety of technologies and prices electricity to allow plant developers to recover their investment plus a reasonable profit. Another way to put it is that an REP system constitutes an open ended power purchase agreement for 10 or 20 years that allows plant builders to receive financing at favorable rates because of the investment's security, due to the guaranteed wholesale power price. In successive generations of plants, some REP systems are designed to reduce the level of the tariff to encourage the industry to become more efficient. Some REP systems have a built in inflation factor to adjust the level of the initial tariff to reflect changes in the value of money. REPs are typically paid for via a supplemental charge attached to all power sales in the electricity system, pooled among the widest set of power users.

REP systems have been successfully applied in Germany and Spain and have recently been introduced in Ontario, France and Italy. Since the inauguration of their current REP system in 2000, the Germans, for instance, have more than doubled the fraction of electricity attributable to renewable energy from 7% to over 14%. Estimates are that German power users will pay on average a maximum of 2.80 euros (\$4.11) per account per month in 2015 when the effect of their REP law will be at its projected maximum, so the REP tariffs do not contribute much to overall power costs to consumers. If it were considered to be more politically acceptable to pay for the surplus power payments attributable to the REP tariffs in part through tax revenues rather than through electric rates, such a system could be designed.

An REP system starts out at “cost plus reasonable profit” but to counteract inefficiency in the renewable energy industry needs to “degress” the tariff levels for successive generations of plants or introduce market elements into pricing. The German tariff steps down in successive new generations of plants and recently the solar rooftop tariff was reduced a higher than usual 9% for 2009 installations while there was higher allowance made for offshore wind to encourage that industry; both moves generated their share of controversy, which is almost inevitable in such an environment. In Spain, there is a market option which encourages renewable generators to heed the needs of the electricity market through a demand-based incentives in addition to a premium paid for clean energy based on the type of technology.

Direct Government Investment

Though less likely to be applied in the US in the current political climate where the levying and spending of tax monies is considered to be an imposition rather than payment for public services, the federal government itself can, as was the case with the Hoover and Bonneville dams, commission renewable generators in situations where risks or payback is too uncertain for private companies to undertake. An effective REP law, however, might make government's involvement in direct power generation limited to the development of research reactors or in commissioning renewable generators for use by government facilities. A commitment by government installations to run their operations largely or entirely on renewable energy could provide a test bed for an all-renewable grid for the broader society.

Though potentially rife with inefficiencies, issuing bonds may be one method for governments to finance new infrastructure. While government bonds are the equivalent of a credit card for the government, the total financed portion of the new infrastructure is stated in the bond. Bond issue may be a necessary evil in building key pieces of infrastructure that are not amenable to a performance-based standard like an REP.

Rebates

Small renewable generators, largely rooftop solar PV arrays, can also receive a rebate directly from a power company or state agency that is based on a formula that reduces the upfront cost to buyers of purchasing and installing this equipment. These incentives require the ready availability of funds either from government coffers or from the utility company itself and would present cash flow problems for these entities if applied to larger generators, as rebate payments would need to be paid in very large chunks to co-finance the new power plants.

Building a National Grid

As is currently the case with the building of long-distance transmission, the federal government will need to take a leading role in building new transmission that will connect load centers with areas which are most favorable for renewable energy development. Main renewable energy areas that require new transmission are: the Great Plains, the intermontane regions of the Rocky Mountains, offshore on the Great Lakes and Pacific and Atlantic Coasts for wind development; desert and semi-arid areas of the West and Southwest for solar thermal and large scale concentrating solar PV; links between geothermal wells and centers of electric demand.

Large states with substantial renewable resources, California and Texas have started planning for zones where transmission lines can be built as renewable generators are built in that zone. As transmission can take many years to build, these lines will bring renewable energy to market as soon as generators are commissioned and ready to generate electricity.

Passing the Buck or Paying the Piper



To transform our energy infrastructure we will need to create policies and economic drivers for change that will provide a steadier stream of revenue to fund this monumental project than the occasional windfall or magnanimous gesture. We will need to "pay the piper" rather than simply "pass the buck".

We have just gone through a period of time in the United States when very little new public infrastructure has been built (with the exception of wired and wireless telecommunications infrastructure). Led by a generation and a half of politicians and economic theorists as well as our own inclinations, Americans have become used to believing that a cheaper, more convenient option is always within reach through reliance on increasingly globalized markets. Our national specialization has become consumption, holding up the export economies of countries with lower labor costs by consuming ever more cheap goods, taking on increasing levels of debt in the process.

We, as a nation, have become unable to pay ourselves living wages to do the work that is required at home to keep standards of living in our country within reach of other advanced industrialized countries, nations that have not taken such a radical path towards deindustrialization and consuming beyond their means. Our specialization as over-consumers has started to shut our own people out of the ability to earn enough through their work to buy what they need to live and thrive; the more goods and services we feel compelled to buy the less we can afford to pay for each good or service, barring a substantial growth in our individual or median national income.

Building a new infrastructure involves years if not decades of work and the construction and manufacture of large physical structures here domestically, all of which cost money.

We will need to organize a way to pay for this infrastructure either through payments for services, like electrical rates or through tax revenue. The notion that opponents of this line of thinking will put forward is that monies collected through taxes or regulated pricing will be inevitably wasted as they have not been distributed through a process of free exchange by independent consumers choosing between alternatives in a marketplace setting.

I would put to those who hold up the ideal of a market with choices equally arrayed for discriminating consumers to choose, that we would lose years of time and much money in creating this market for infrastructure services, a novelty within world history. Already we have seen experiments in various electric systems, such as California, with deregulation but with little positive learned about the nature of these goods and services and their most efficient means of delivery.

Instead, we need to face the music and start reckoning that we must spend more on necessary clean energy infrastructure to ensure that we have a tolerable or even pleasant way of life as oil depletes and carbon concentrations rise. Spending more, whether through electric rates or taxes means paying one's neighbors and friends wages that they can live with to do the work that needs to be done to keep our United States at or near the lead of the next industrial revolution.

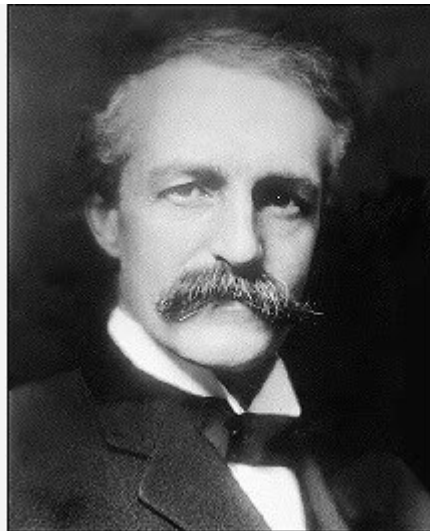
Those who stubbornly insist on paying only the cheapest price, yet want a new clean energy infrastructure are for all practical purposes waiting for a rich charitable patron or technological windfall, to "make it all better". Technological optimists, spoiled by the microelectronics and Internet revolutions, hold out for the ultimate cheap generation and storage solutions that will match our current price expectations. We can hope this will happen but we cannot bank on hope alone. "Free" market enthusiasts look around for the next better deal or ways to push pricing down to current price expectations against what looks like to be a permanent bull market (with ever-rising prices) for commodities, the commodities of which energy and transport infrastructure are made. The reality of the world however does not always conform to one's preferred social or economic ideal.

If we look around though, we will see that we together can be our own patrons; we as a culture can place a higher value on energy and our own livelihoods, as workers and investors in our own society. We can pay somewhat more for something that we have taken for granted but that now requires our attention and sustained effort.

(originally published October 19, 2008)

In the first three parts of this series for policymakers I have reviewed how we can fairly rapidly transfer our transport energy demand from exhaustible fossil fuels to renewably generated electricity, how that electricity can be generated, and what policy instruments are available to help build the Renewable Electron Economy. We have determined that this undertaking will require substantial investment and increased overall expenditure for energy and transport yet will be not nearly as expensive as continuation of the status quo. However, a key factor in achieving the most ambitious climate protection and energy independence goals, is the rapid implementation of energy saving techniques and technologies, which are facilitated by the use of a selection of key devices, most of which are driven by electricity.

Energy Conservation and Energy Efficiency



Viewing along with his father the waste of natural resources in the 19th Century US, Gifford Pinchot (1865-1946) was one of the founders of the movement towards conservation of natural resources. Coining the term the "conservation ethic", Pinchot was the first leader of the US Forest Service, appointed by Theodore Roosevelt.

Most analysts acknowledge that the least expensive and most rapid route to meet the first several "tranches" of our carbon emissions reduction and energy independence goals is by avoiding having to generate as much electricity or drill for as much fossil fuel for transportation in the first place. Energy efficiency (EE) and energy conservation are different but related concepts, though they are often confused. Energy efficiency means that users of powered devices can get the same enjoyment or use out of a more efficient device that uses less energy. Energy conservation is a planful pattern of human action by which energy use is avoided. Energy efficiency and energy conservation can be more or less linked together. As a concrete day-to-day measure, energy efficiency is considered to be more effective than energy conservation because once a device is installed, it takes the choice to waste energy out of the hands of people, while

conservation requires human effort and choice. On the other hand, the value of energy efficiency is enhanced and its implementation facilitated by an pre-existing ethic of energy conservation that may permeate a society as a whole; investors and governments are more likely to prioritize energy efficiency investments if they believe that resources are valuable, limited and ought to be conserved.

The importance of an ethic of conservation in promoting both energy efficiency and renewable energy has been underplayed in part because of the political defeat of Jimmy Carter in 1980, who was the most powerful public figure in recent memory to actively promote energy efficiency and resource conservation. Historian and political commentator Andrew Bacevich has contrasted unpopularity of Carter's image as a prudent conservator of resources versus the then more attractive image of the swashbuckling Ronald Reagan who painted the picture of an America of infinite resources and prosperity. Bacevich sees Reagan as the "prophet of profligacy" an attitude, because of Reagan's political influence to this day, that has colored the American view of the ethic of conservation. At the moment we seem to be at a turning point against this decades long stereotyping of the pursuit of conservation, where green is fashionable and oil companies are declaring in expensive TV commercials that conservation is an imperative.

While on a national level, support for energy efficiency has been inconsistent, California's state government has since the initial oil shocks of the 1970's developed a set of energy efficiency regulations of utilities and building standards that remain the state of the art within the US. California's energy use per capita has remained steady since the 1970's due to a successful energy regulatory environment and despite rising population in hotter areas of the state away from the temperate coast. Some of the early, fairly easy national measures for energy efficiency can be achieved by adopting wholesale or revised versions of California's regulatory culture.

Energy Efficiency: Generating "Negawatts"

$$\text{efficiency} = \frac{E_{(out)}}{E_{(in)}} \times 100$$

Energy efficiency is a measurable quantity, a percentage of energy or work that results from energy that is input into a process. Efficiency is expressed as a percentage between 0 and 100; e.g. a (very efficient) process with 95% efficiency converts 95% of the energy input into useful work.

The energy guru Amory Lovins coined the term "negawatts" to describe how gains in energy efficiency can avoid the production of large quantities of energy, meaning "avoided megawatts". Lovins likes to call energy efficiency and negawatts "the free lunch that you're paid to eat". Highly influential, Lovins is relentlessly up-beat about how

energy efficiency is a sound business and product design practice, though his enthusiasm downplays the challenges facing energy efficiency in the American context where energy is still relatively cheap. While in Europe and Japan, the higher cost of energy facilitates investment in energy efficiency without incentives, in the US, systems of incentives have been necessary, most notably successful in California, to encourage significant adoption of energy efficiency measures.

One can compare the price of negawatts to megawatts as a decision-making tool. A modern power natural gas power plant can cost somewhere around \$2500/kilowatt of power to build. The cost of power from this plant can, in addition, rise as the price of the fuel (inevitably) goes up. On the other hand, an efficient lighting project, especially where there is a substantial leap downward in wattage between old and new fixtures, can cost around \$1000/kilowatt, fuel "included", which will in effect becomes cheaper as the price of power rises (or conversely, the return on investment will accelerate). Not all energy efficiency projects are as inexpensive but the same principle applies that as the price of power goes up, the return on investment on an installed energy efficiency project gets more favorable.

If energy efficiency and new clean generation are not played off as an "either/or" proposition, the extra expense of new clean generation will spur energy efficiency investment, as the higher per kilowatt-hour costs of a new technology will make investment in energy efficiency all the more attractive. More efficient use of energy will in turn lower the overall costs of building a new clean infrastructure as less generation capacity will need to be built. The interplay between new clean generation and energy efficiency then will function as a "virtuous circle".

Utility Revenue Decoupling and Energy Efficiency



California Energy Commissioner Art Rosenfeld is sometimes called the "father" of energy efficiency in California. A trained physicist, Rosenfeld in the 1970's realized that many of the energy challenges facing the US could be met by increasing the efficiency of devices and processes. Many of the efficiency programs in California were devised or influenced by Rosenfeld, whose current interests include "cool-colored" materials and designing HVAC systems with local climatic conditions in mind.

In 1982, to align the interests of the investor-owned utilities with the State of California's goal to increase energy efficiency, the California Public Utilities Commission created an innovative system by which utilities would not suffer decreases in revenue by reducing power sales. The decoupling of utility revenues mandated that utilities invest a certain amount in energy efficiency programs, usually through rebates for energy efficient devices and device installation, yet allowed the utilities to recover lost revenues from these reductions in power sales by increases in power rates the subsequent years. These increases, in turn, facilitated further investments in energy efficiency as higher power costs spurred power end users to put more money into more efficient end-use devices. California has higher power costs than surrounding states but power use has remained around 7500 kWh per year per person since 1977 as power use has risen throughout the United States to an average of 12,000 kWh per year.

Utilities under decoupling regulation have found that investment in energy efficiency is a way for them to avoid or postpone large scale capital investments in new power contracts or transmission and distribution infrastructure. Northern California's large investor owned utility PG&E for instance has invested three times as much in energy efficiency as is mandated by the state for just these reasons. In addition, investment in energy efficiency is good public relations in an era in which being green is considered a public virtue.

Recent policy proposals including that of the Barack Obama campaign to increase energy efficiency throughout the US suggest making revenue decoupling a national requirement for all utility regulatory structures.

Green Design: Guiding Natural Energy Flows



Making a statement about green design, the Alberici construction company of Missouri built their new headquarters as one of the highest scoring LEED Platinum buildings. The architects re-used the shell of a 50 year old manufacturing and office facility, orienting the new facades of the rebuilt structure towards the south to capture more winter sun and optimized natural ventilation flows to increase energy efficiency and improve indoor air quality.

Energy supply in a renewable electron economy means tapping into natural energy flows or gradients and using them to generate electricity to power useful devices. But what if those currents of natural energy and material flow had desirable uses in their stronger, unconverted natural forms? As we have already established, renewable generators are, at least with current technology, not inexpensive and like most electric generators, convert only a fraction (from 10 to 40%) of the primary energy they receive into electricity.

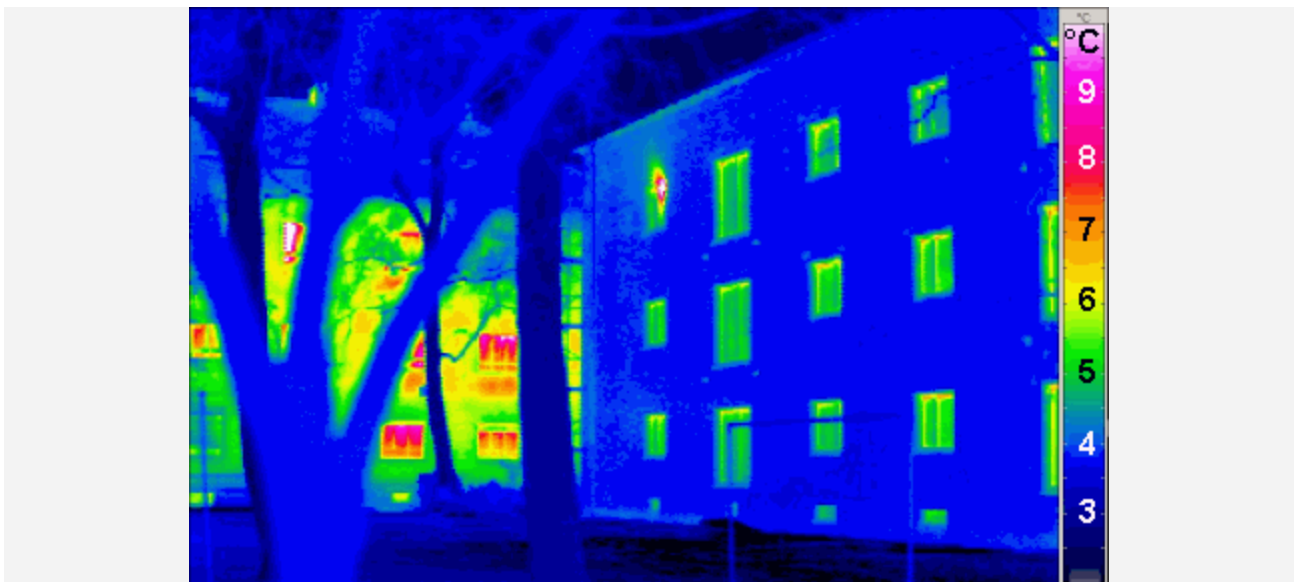
One way to think of green design and building principles is that they are able to route natural energy flows to serve a desired human end, avoiding the losses and expense associated with converting the energy into a new form, like electricity. For instance the heat from sunlight or from the bodily warmth of people and animals can be used to keep the interior of buildings warm during the winter with the proper materials and construction. Or natural light can be used to light the interior of buildings through windows and skylights or through new fiber-optic daylighting systems and solar tubes. Wind can be used to cool a building through wind towers in hot dry climates. An awareness of these natural flows and gradients is one of the most important tools of the green architect or designer.

Advanced materials also allow green buildings to work against natural energy flows if so intended by the building's designers or occupants to keep a space warm or cold, dark

or light. Superinsulation and advanced window technologies allow buildings to use almost no energy to maintain comfortable interior temperatures with minimal heating or cooling energy required. Older technologies like straw-bale design and adobe walls can have a similar effect in declaring our intention to keep a space warm or cool, fighting against the entropic tendency for heat and moisture to evenly disperse across natural barriers. Pre-fabricated building and building parts allow for more precise design tolerances and tighter buildings as factory construction is more precise than what can occur on site.

Near-zero, Net-Zero and Plus-Energy Buildings

While green building encompasses more than a focus on energy usage, reducing the energy use and attributable greenhouse gas emissions of buildings is one of the key concerns of green builders today, contributing for instance approximately one-third of the potential points to the LEED green building rating systems. Near zero energy buildings are achieved with the application of efficient building technologies, green building principles and some on-site renewable energy generators, most often solar PV panels. However, a near-zero energy residential building can also be achieved exclusively through the application of hyperefficient building technologies without on-site renewable energy capture and generation.



Superinsulation is a characteristic of most near, net- and plus-energy buildings. In these infrared thermograms, the passive building on the right is emitting much less heat than the ordinary building on the left as it is more tightly constructed and has walls with a much higher insulation value; this allows the passive building to use 15% of the energy of ordinary buildings to heat, cool and ventilate.

One building system that can produce near zero energy buildings are “passive” buildings or houses that use ambient energy from the sun to be heated in the winter and cool from the upper layers of the ground to remain cool in the summer. Passive houses or buildings

are super-insulated and use an air-to-air heat exchanger (driven by small electric motors) to preheat or pre-cool incoming air with exhaust air thereby keeping interior air fresh while preserving the desired interior temperature. A passive house can use 15% of the energy of a non-passive house for space-conditioning; furthermore, the heat given off by lighting can contribute significantly to the warmth of the house in the winter leading to a two-for-one effect.

Building closer to the ground or using thick earthen or naturally insulated walls can in almost all climates reduce the need for space conditioning, as the temperature of the ground and groundwater remains fairly constant relative to the air temperature. Also the introduction of walls or floors as thermal masses gives architects another tool to reduce building energy usage by storing heat or “cool” in these masses for slow release later on. The “Earthships” by New Mexico architect Mike Reynolds, use the thermal mass of thick walls and thoughtful design in relationship to their environment to reduce or eliminate the need for space conditioning. A new technology, borehole thermal energy storage or BTES, is a means to use installations of thermal masses in the ground to store the heat of the sun during the summer which remarkably 6 to 9 months later is still available during the winter to heat buildings and other processes.



This net zero energy building in Los Angeles, the Audubon Center at Debs Park, has an innovative system of rooftop solar thermal collectors and absorption cooling which use solar heated water to both heat and cool the well-insulated interior space (also a LEED Platinum building).

To push beyond near-zero energy threshold, net-zero and plus-energy buildings require the application, sometimes liberally, of PV or wind turbine technologies to cover the internal uses of energy in the building, even as the buildings exchanges energy with the local utility via the grid. The mix of building efficiency vs. on-site power generation technologies will be influenced by the relative cost of these technologies, the uses of the

building (residential, office, industrial), the local climate, the intentions and commitments of the builders and owners, and renewable energy resources available. It may be more inexpensive at one point in time or place to apply efficient building technologies but at a point of diminishing returns, the purchase of PV panels or an on-site wind turbine may become the most feasible option. With more power usage per square foot, to achieve net zero or plus-energy, requires of necessity more on-site generation. Compared to the building techniques of the last couple centuries that depend on energy subsidy from coal, gas, oil or wood for comfort and functionality, using current and emerging building technologies in new buildings makes it easier to approach the net-zero energy ideal.

Electricity and Energy Efficiency Retrofits of Existing Buildings

Reaching the extremes of energy efficiency is easier in new construction using the latest or revived ancient energy efficient techniques. One key policy measure for enhancing the future energy efficiency of buildings are national building standards that may be based on California's Title 24, a system by which new construction is pushed to become more efficient with every successive generation of buildings. Just as in its utility laws, California now has 3 decades of experience in designing effective building laws from which most other states and the national government can draw in designing a broader system.

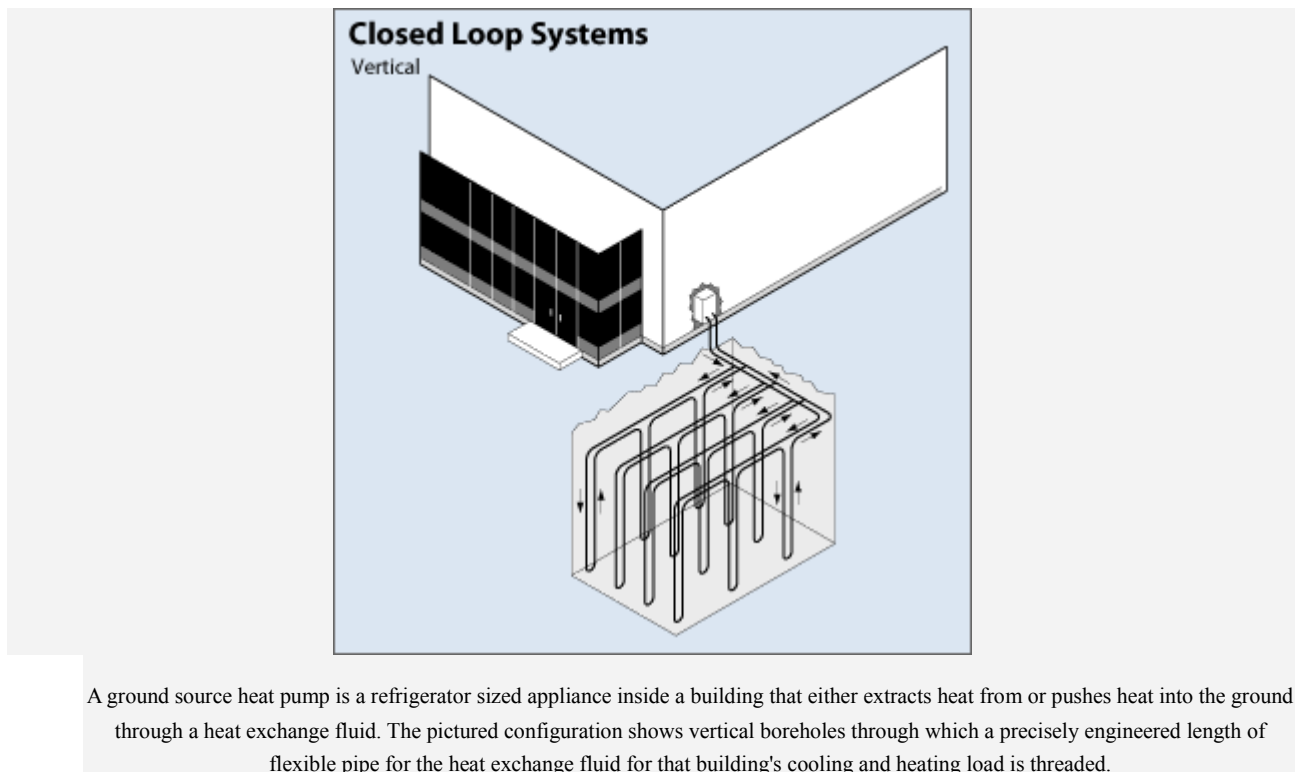
However for the next half a century or so, wherever we live, we will be living with many buildings that were built without much regard for their energy use. Many of these buildings can be made tighter and better insulated but will only in rare cases achieve the standards of hyperefficient new construction.

Buildings typically now draw their energy from a combination of wholesale generated electricity from the grid, piped-in natural gas, propane from tanks, and occasionally wood and wood pellets. It is unfortunate that fossil fuels predominate in this mix. As it turns out, if more buildings used electricity for more of their daily operations, building energy use could be halved for most energy intensive tasks. Furthermore, as the Renewable Electron Economy concept suggests, electrical energy which once came from fossil sources can be generated by renewable electric generators, thereby giving all-electric buildings the potential to be carbon neutral in their operations now or at some point in the future.

Furthermore, as we do not have the luxury of building an entire new building stock of near zero and net zero buildings from the ground up, high efficiency electric appliances and systems are fairly easy retrofits for existing buildings, though to implement these on a large scale sometimes requires an incentive structure to facilitate the move.

Heat Pumps: Ground Source, Hybrid Air/Ground, Air Source and BTES Linked

About 60% of the 40% of total US energy consumption (meaning 24% of total energy use) attributable to buildings is used by heating, ventilation and cooling systems, a.k.a space conditioning or HVAC, and water heating. Even in severe climates, this amount can be cut to half or less of current usage by the use of more efficient HVAC technologies most of which require only electricity as its energy input. Daily combustion of fossil fuels for space conditioning can be eliminated in most climates by the use of (electrically-driven) heat pumps that can pull heat out of or put heat into spaces as desired by building users. Heat pumps in combination with fans and water pumps distribute heat or cool either using an air-duct or a fluid-based radiant heat or cool distribution system in a building, thus can substitute for both an air conditioning and a heating system. Heat pumps operate using the same principle as a refrigerator but unlike a refrigerator can also work in reverse. Not only can energy use be cut by using properly designed heat pumps but dependence on natural gas and heating oil can be eliminated for space conditioning, allowing at some point in the future all energy for a building to come from renewable electric generators.



The most efficient, though highest price heat pumps used for space conditioning are ground source and groundwater source heat pumps (GSHPs) that use the substantial thermal mass, conductivity, and consistent year-round temperature of the ground or groundwater as either the heat source or the heat sink. The expense of GSHPs comes from the need to build a ground loop by trenching or by drilling boreholes several

hundred feet deep through which a tube with a heat transfer fluid is drawn. The size of the GSHP's ground loop has to do with the heating and cooling load and the soil characteristics. Sometimes called geothermal or geoexchange heat pumps, they can also use the excess heat that is extracted from the building or the ground to heat some of the hot water used in the building, though one could build a dedicated ground-source water heating loop as well for consistent all-year hot water heating.

GSHPs can reduce the energy needed to cool by half and to heat a house by as much as two-thirds with the energy requirements purely electric: the fan, compressor, and pump energy required to circulate the heat exchange fluid, extract the heat and distribute the heat or cool throughout the building. However, to reduce the size of the ground loop and therefore expense, it makes sense to tighten up and insulate the house.

Air-source heat pumps or hybrid air/ground heat pumps are less expensive than a ground source unit because they either have no ground loop (air-source) or a much shorter ground loop (hybrid). Less efficient than ground source units, these heat pumps are however good choices for milder climates and are improvements over electric resistance, oil and natural gas heat. Air source and air/ground heat pumps as well can be used to heat hot water further reducing the need for natural gas. For passive houses, the remaining heating and cooling load that cannot be fulfilled through passive means can be supplemented a number of ways but some use a micro ground loop under the house to extract and expel heat from the house may suffice, given the superinsulated nature of the house.

With the advent of borehole thermal energy storage, electric heat pumps can be used to deposit or extract heat from the seasonal thermal energy store, which will, in some applications, reduce the amount of energy required to condition buildings. These pumps do not require a compressor, thereby reducing the energy requirement for BTES.

Efficient (Gourmet) Electric Kitchens: Induction Cooktops and Electric Infrared Grilling

While space conditioning and water heating together account for 60% of the energy used by buildings in the US, another example of where a new electric technology can make substantial contributions to lowering building energy use is in the 4% of building energy used in cooking. Popular in Europe and growing in popularity in the US, magnetic induction cooking uses the induction effect of a high frequency magnet to heat the metal of a steel or iron pan or pot, thereby avoiding heating the surrounding air or the stovetop itself. Induction cooktops use 84% of the energy input to heat food as compared to 40% for gas or 70% for electric resistance cooktops. Furthermore induction cooktops are more minutely controllable, quicker, and safer as the cookware gets hot but the stove doesn't.



GE demonstrates one of the favorable characteristics of induction cooktops through showing how ice-cubes do not melt as water boils on adjacent part of the induction cooking surface: only the metal cookware gets hot not the cooking surface. Induction cooking is also notably fast and precise.

The efficiency of induction cooktops combined with their functional advantages over gas will help electric cooktops and thereby all-electric kitchens gain market share over gas, which has been favored by demanding home cooks and chefs. The complaint that some chefs have that they cannot see the power and heat-setting of an induction cooktop as compared to gas can be easily overcome with the invention of a simple visual indicator of the power level for an induction stove.

While the attraction to open flames remains for many a signature of the cooking process, in the world of renewable fuels, charcoal and wood firing still produce the desirable flames, glow, chars and flavors that people have enjoyed for millenia. However, those in the grilling world who seek more convenience and less smoke for daily use, now prize the new infrared grilling technology, which can be fueled with natural gas, propane and now electric elements. The latter electric infrared grills can use renewably generated electricity and are easily controllable and more efficient than their fossil fuel equivalents. The further development and distribution of electric infrared grilling technology will allow all-electric cooking to reproduce or exceed the cooking results from fossil fuels with the same convenience.

While these issues may seem small, opting out of and eventually shutting down natural gas distribution to households and commercial kitchens without a decrease in end-user utility can help buildings become carbon neutral more quickly. Furthermore, the development of more efficient and cost-effective electricity-driven sources of heat can replace the use of natural gas for industrial processes which account for 8% of US total energy use.

Key Technologies for More Energy Efficient, Carbon Neutral Living

Including those mentioned above, listed below are some of the key technologies that will help us achieve energy independence and carbon neutrality more quickly.

- 1) Heat pumps: ground source, air source, hybrid and with bore hole thermal energy storage
- 2) Super-glass (low emissivity, selectively coated, insulated) and super-windows
- 3) High-R Insulation and structural insulated panels
- 4) Efficient Fluorescent and Efficient LED Lighting
- 5) Fiber-optic solar lighting and advanced skylights for daylighting
- 6) Intelligent building, lighting, and appliance controls
- 7) Light-colored and "cool-colored" building and paving materials (that reduce the heat island effect of the built environment and building heat loads)
- '8) Solar thermal water and space heating
- 9) Variable Frequency Drives (electronically adjusting pump and fan speeds to energy demand)
- 10) Weatherproofing and tighter building envelope standards (with testing)
- 11) Radiant heating (using water rather than air as the heat transfer medium in a building)
- 12) Induction cooktops, convection ovens and electric infrared grilling

Quality Assurance and Certification in Energy Efficiency

More so than in the generation of electricity or extraction of energy, the implementation of energy efficient technologies either through the private market or through government programs requires extensive testing by government or trusted 3rd party agencies to make sure that promised energy savings will be realized by a new technology. The potential for fraud in promising "more for less" or for improper installation of a technology requires oversight by both private and public regulators. Paired with the decoupling of utility revenues combined with a mandate to invest in energy efficiency, power utilities have an interest in monitoring the effectiveness of energy efficiency measures.

Energy Efficiency in Transport: Short term and Long-Term Solutions

One of the key features of the Renewable Electron Economy is the replacement of petroleum with electricity as the energy carrier for transportation. However this transfer will take place at varying speeds depending on the future cost and availability of petroleum as well as political support for electrification of transportation. Petroleum and natural gas will be around for at least a decade or two in force and in vestiges in the following decades. Increasing the efficiency of internal combustion drive vehicles will have a role even as we transition to vastly more efficient electric transport.

One of the motivations to transfer transport energy to electricity is the staggering increase in efficiency that electric motors represent over petroleum and natural-gas fueled internal combustion engines: the 90% efficiency of electric motors contrasts favorably with the 25-30% efficiency of the modern internal combustion engine. A vehicle of similar mass and design would have 3 or more times the mileage as an electric vehicle rather than a traditional petroleum-burning car.

Short-term Solutions

In the first installment of this mini-series, I compiled a list of short-term solutions related to how we can reduce vehicle miles traveled rapidly by the more efficient operation of both our autonomous and public vehicle infrastructure and the use of information technologies. Below are some specific measures that can be applied to vehicles themselves.

Vehicle Lightweighting



Aptera, with their revolutionary Typ-1, is radically restyling passenger vehicles to save weight and energy. Though classified as a motorcycle, Aptera has targeted exceeding passenger car safety standards in their design.

While the internal combustion engine is near the end of its development trajectory, a number of innovators in the area of vehicle materials are attempting to show that the use of lightweight body materials such as carbon fiber can reduce conventional vehicle mass substantially without endangering vehicle safety. Amory Lovins has long championed the use of carbon fiber to double vehicle efficiency, claiming that bulky vehicles with advanced lightweight materials could have . The German company Loremo and the American company Aptera have also suggested radical, lightweight vehicle designs as

ways to create hyperefficient vehicles that would either have a small internal combustion or an electric motor.

Vehicle Efficiency Standards and Automaker Penalties vs. Gas Taxes

Mandating vehicle efficiency standards has been an uphill battle in the US, requiring American automakers to work against their own design culture and the tendencies of American auto buyers to prefer large and powerful vehicles in an environment of cheap and abundant petroleum. While vehicle efficiency standards are, in the culture of environmental reform and public virtue, viewed to be a necessity to impress on upon both automakers and the public that optimality of fuel efficiency, higher gas taxes in Japan and European countries have been a far more effective means of compelling automakers and auto buyers to conserve energy and choose more efficient vehicles.

If US legislators and environmental pressure groups are at all serious about encouraging gasoline powered vehicles to use gasoline more wisely, they will need to challenge the Cheap Energy Contract with substantial rises in fuel taxes. This will take more courage on the part of these actors as simply asking for higher fuel efficiency standards puts the onus on automakers to lead the market. While the shortsightedness of US automakers is truly lamentable, legislators so far have not succeeded in transforming that culture through vehicle efficiency mandates. Those who cite the current success of Toyota and other foreign car makers vis-à-vis US makers forget that, among other things, the headquarters of these companies are in countries with fuel that costs at least twice as much as it does in the US. Fuel efficiency standards require US automakers to lead the efficiency charge, which requires them to occupy a position of moral and environmental leadership without the aide of high fuel prices.

A compromise that avoids some of the negative political fallout of an across the board gas tax hike is a varying tax surcharge that keeps the price of fuel above a certain level blocking efforts by oil producers to artificially lower prices or to smooth over the effects of temporary drops in demand. This fuel "price floor" would be explainable to constituents who should at some point understand that the movement to higher fuel prices is inevitable and energy efficiency in transport socially desirable.

Longer-term Measure: Shifting to Electric Drive

As discussed in the first installment of this series, the shift to electric drive is by far the most effective means of conserving energy resources. The current generation of hybrids use electric motors to provide an assist for relatively inefficient gasoline internal combustion engines. Plug in hybrids and electric vehicles have the potential to double or treble the efficiency of automobile drivetrains.

Price Signals and Energy Efficiency

Just as with the finance of new clean energy generation technologies, the price of energy is key in spurring energy efficiency investment and energy conservation. As indicated above, price signals are some of the most effective ways to spur private parties to cut their energy use; the implementation of those price signals through policy instruments needs to proceed at an urgent pace yet not so rapidly as to encourage backlash against the necessary efforts that we all must undertake to help preserve a favorable climate. Carbon taxes, fees and cap and trade systems will in all likelihood serve to spur investment in energy efficiency, though the degree to which they do will depend on the level of the resulting carbon price as well as the ultimate efficiency of the chosen mechanism. These instruments will in their early stages in all probability be more effective in spurring energy efficiency investments than they will in stimulating the building of new clean electricity generation as the relative cost of the latter is in many cases too high.