The Fake Fire Brigade - How We Cheat Ourselves about our Energy Future

Posted by nate hagens on June 28, 2010 - 8:00am

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Editor's note: Below is a guest post from Hannes Kunz, President of Institute for Integrated Economic Research (IIER). Hannes has a PhD in Economics from St. Gallen University and resides in Zurich Switzerland. IIER, is a non-profit organization that integrates research from three different areas: the financial/economic system, energy and natural resources, and human behavior. Their objective is to aid policymakers in developing strategies that result in more benign trajectories after global growth ends. Hannes is also a friend and co-author of two papers with me, (pub. pending), 'Net Energy and Time', and 'Net Energy and Variability'.

On June 15, 2010, when U.S. President Obama responded to the dramatic oil spill in the Gulf of Mexico during his Oval Office speech, he not only included the list of things the government wants to do about the imminent problem, but also urged the country to "transition away from fossil fuels" and to "jump start the clean energy industry". His pledge is in line with many of his predecessors, and with other leaders around the world, who for years now have supported renewable energy technologies. This is particularly true in Europe, where installed capacity for renewables has grown significantly during the past ten years. And even the U.S. - while slow in introducing renewable electricity technologies - to date has produced a significant amount of alternative fuels primarily through the mandatory addition of ethanol to gasoline.

For many people hoping for a future with less greenhouse gases and less environmental damage this focus on renewable energies might sound like a step in the right direction; for those who want low cost energy, maybe less so. But what both sides of the discussion forget is something quite simple: an energy future without fossil fuels will eventually arrive, and there is no way to extend current energy usage patterns and delivery systems into the future. In a nutshell: our current plans will fail. Let's explore why that is.

The Fake Fire Brigade - How We Cheat Ourselves about our Energy Future

A comment to begin with: IIER is a research organization trying to neutrally assess the situation of our societies, and with that, find out what strategies work and which ones do not. By no means are we trying to promote or discourage any specific energy alternative, and we have no vested interest in anything else than stable future energy supplies. What you read below is the result of years of thorough analysis and research. When we began, we were completely neutral towards any particular solution and technology, and our only aim was to understand the implications of various energy scenarios on the future of our societies. Now, we have an opinion.

The longer straw - the future of fossil fuels (and most other

resources)

The future of fossil fuels, particularly of oil, but also many other resources including water and minerals, looks problematic. People keep discussing proven reserves and whether peak oil already has arrived or not. Unfortunately, we will only be able to put this argument to rest in hindsight. But what is more important is the fact that - no matter how much additional oil we can still retrieve - future barrels will be much more difficult to extract relative to the past.

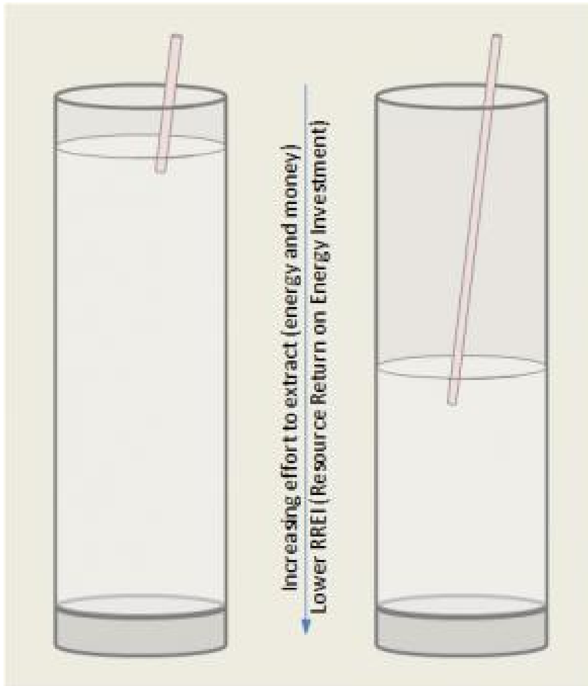

Fig 1. The mile-long glass

Drilling a hole in the desert and waiting for black gold to gush out is infinitely less complex than drilling a much deeper hole 5000 feet under water, as the public is now painfully beginning to understand. Many experts agree that we probably have used about 40-50% of recoverable oil. It is difficult to prove such numbers, but we may for a minute assume that this is true. For pessimists, this makes our glass half empty. For optimists, it remains half full. This has been the exact argument the energy community has been having, to little avail, so let's play with that analogy some more: our oil reserves can be compared with a 1 mile deep glass full of our favorite drink. Getting the first sips is easy. Whenever we are thirsty, we lower a straw into the fluid and drink as much as we like. After a while, that straw might become too short, so we have to find a longer one. Not really a problem. We might even get better at making straws for a while. And so it continues.

But once we are half a mile down into this huge glass, the straw will be so long that one might need help to even hold it, and we will most likely require help to suck hard enough to make the fluid come all the way up. What has happened? We still have half of our favorite drink left, but the efforts to get to it are becoming increasingly painful, significantly diminishing the net benefit of that next sip. And so we might (have to) give up drinking long before the glass is empty, just because its too difficult to get at the fluid in a meaningful way, and because the effort of sucking eventually exceeds the benefit and joy from each sip.

The concept behind our "mile-long glass" analogy unfortunately applies to almost every raw material and energy source we are currently using. The more we have extracted, the more difficult it becomes to get to the next unit. Our organization (IIER) looks at this phenomenon using the term "Resource Return on Energy Investment" (RREI), which is based on established approaches used for Energy Returns on (Energy) Investment (EROI). It describes the amount of effort (energy) needed to get one unit of a resource we want to extract. To extract the next unit, our effort typically increases compared to the past, as we have mostly exploited the easy finds and must pursue the ones that are further away, harder to get, more difficult to secure politically, or any such combination. Over time, this increasing effort makes the production less and less useful to societies. Or to use our drinking straw example: at one point sucking out more from that glass exhausts us so much (e.g. the energy invested per sip becomes so big) that we will have to stop our effort and turn to something else, or - if there is no equivalent alternative - drink less.

When looking at RREI, almost all resources currently used in human processes show declines. Less "easy oil" means that we have to drill in hostile environments deep under the surface of oceans, lower ore grades mean that we have to move four times as much rock to extract the same amount of copper when compared to a couple of decades ago, and the depletion of groundwater sources translates to getting drinking water from desalination plants or from fossil (non-renewable) aquifers far away, at much higher energy cost.

This decline in easily extractable resources and the increased effort to retrieve them is much more important than the exact year when peak production of a particular resource actually occurs. It is today's reality, and helps explain why we are drilling at the bottom of the ocean at depths where no human being could survive for even a second.

Renewable energies - the fake fire brigade

So while some haven't really recognized that we will soon run into serious problems from traditional fossil fuels, others are already preparing a "brighter future", which will bring independence from coal, oil and gas, with far lower carbon dioxide emissions to boot. In many European countries, thanks to subsidies and purchasing guarantees, large amounts of renewable electricity generation capacity has been built during the last decade, and in the U.S., corn based ethanol now has a government-mandated share of up to 10% in fuel gasoline. But let us not fool ourselves: during those 10 years, despite all the relative successes, renewable energies (including hydropower) grew by far less compared to the global increase in total energy consumption. Overall, our global energy delivery system continues to be as dependent on fossil fuels as ever before, or even more so. On top of that, even those renewable technologies are mostly based on fossil fuel inputs, which are either used during the manufacturing of the equipment, or even during production and processing (e.g. biofuels).

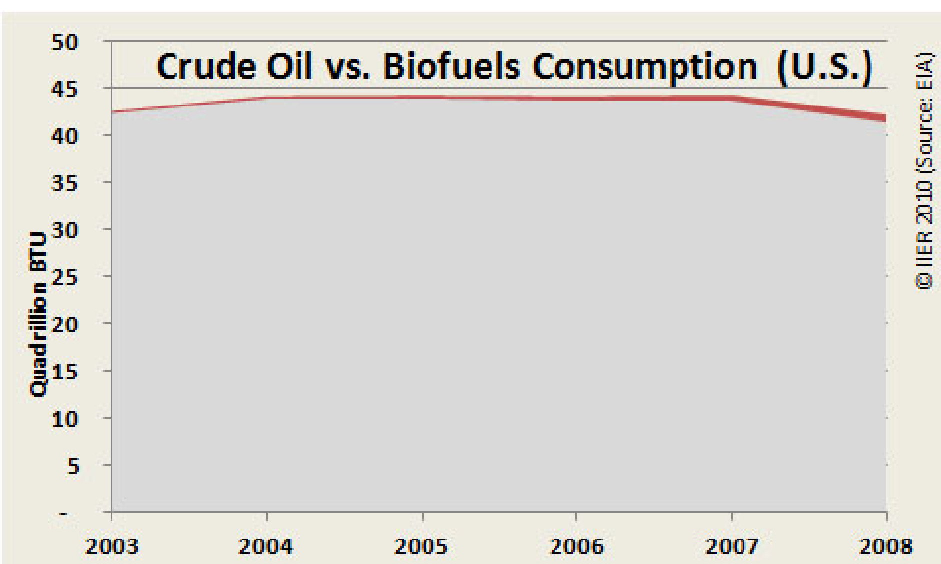

Fig 2. Biofuels (red) vs. crude oil (gray) consumption in the U.S. (EIA)

One of IIER's key objectives is to understand what the future of energy delivery systems will look like. We know that we will have to face a future with less and ultimately no fossil fuels. The question remains how to prepare for this eventuality. Most technological optimists believe that this challenge can be met with some combination of biofuels, renewable electricity generation technologies, electric cars, smart grids, and many other investments. However, when we examine these technologies more closely, none of these so-called "solutions" come close to providing any relief, quite the contrary.

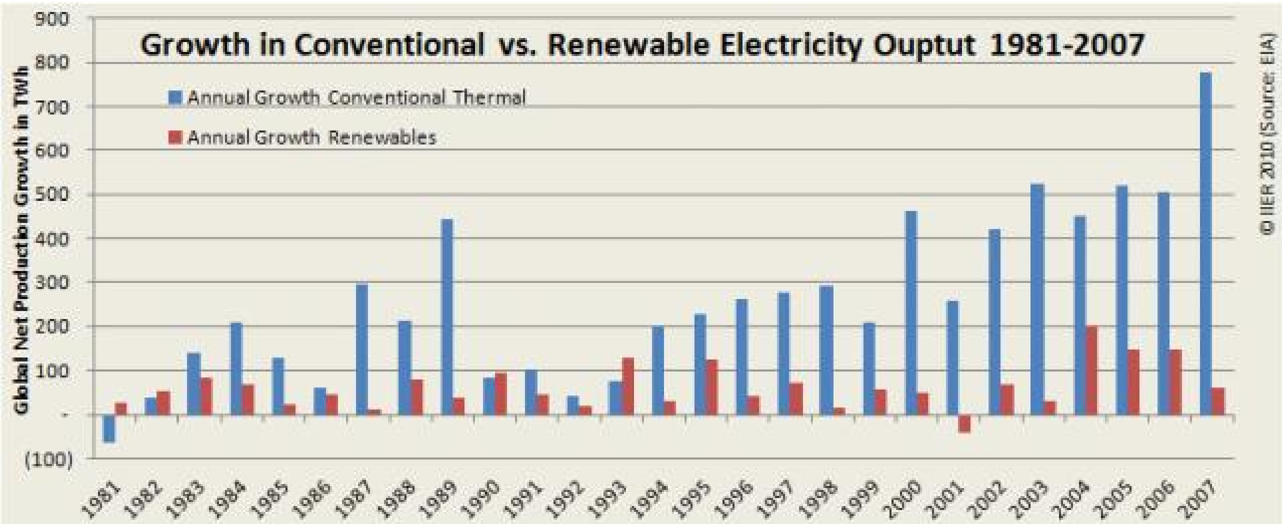

Fig 3. Growth of Renewable (incl. hydro power) vs. Fossil Fuel Generation 1981-2007 (EIA)

As Robert Rapier, a well-respected energy analyst, puts it: "We are running out of traditional energy sources, which can be compared to our house being on fire. While that happens, many people linger around the burning building and pretend to be firemen, mimicking their actions, carrying some equipment, shouting commands - but actually they have no real water, no real skills, no appropriate tools. That way your house will burn to the ground because the "real" firemen never showed up, as everybody thinks there are more than enough firemen on site." This is exactly what it is: when taking a closer look, most - almost all - of the renewable energy technologies promoted today won't solve any of our future energy problems. Let's get into the details using two examples. Renewable electricity generation, and biofuels. In order to keep this article halfway short, we will only make the general case, but we are happy to back up our claims with hard facts.

The future of electricity – a shaky one

Today's electricity grids are key building blocks of modern civilizations. Advanced economies depend on the reliable and discretionary delivery of power to every single socket. Our way of living, which includes the ability to read this article, wouldn't be possible without. Unfortunately, delivering stable electricity poses a significant challenge to grid operators, as energy production and consumption in any moment need to be matched explicitly. Storage is expensive, technologically complex, and always incurs losses, which is why power grids have become the perfect example of just-in-time supply chains. Whenever there is growing demand, additional power generation capacity comes online within seconds, and likewise, falling demand leads to the immediate withdrawal of an equal amount of generation capacity.

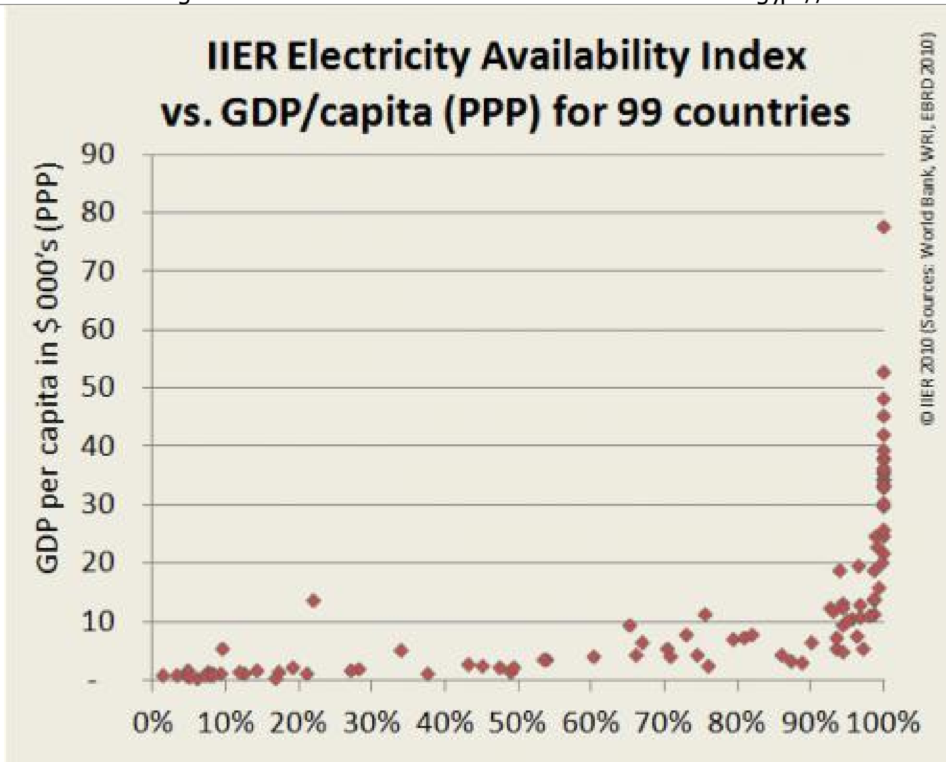

Fig 4. Electricity Availability versus GDP per capita

Having access to stable power grids seems to be positively correlated with economic output as IIER's EAI (Electricity Availability Index) shows. It is based on availability (percent of population with access to electricity) and reliability (number and duration of blackouts). When looking at the chart, it becomes obvious that it seems almost impossible for a country to arrive at a per-capita GDP significantly above US$ 10'000 (2007 dollars, adjusted for purchasing power parity) in environments where electricity isn't a stable and reliable commodity. When thinking about it, this isn't so surprising, as most industrial and commercial processes require stable electricity in large quantities, and its absence simply makes many things impossible.

Right now, all our electricity delivery systems are almost fully controlled from the supply-side, i.e. no usage restrictions apply, which is why we benefit so much. Customers don't have to pre-order a certain amount of electricity before they can turn on a machine, a computer, or start cooking, but instead just do so, mostly oblivious to the fact that someone somewhere in a grid operations center will turn on a gas turbine, or let some water flow downstream, just because we flip a switch. A preliminary analysis conducted by IIER shows that less than 10% of electricity demand can theoretically be supply-controlled without severely impacting societies. Computers, machines, air conditioners, stoves and ovens, and most other industrial and household devices are those things we want to use when we need them. But even where grid operators theoretically could shift certain electricity uses to off-peak times without disrupting our lives, this comes at the significant price of introducing a smart grid infrastructure, and new devices capable of being controlled remotely. Another fake fireman.

Thus, no matter how hard we try, electricity systems will continue to rely mostly on supply side adjustments. Today, this is manageable, because most sources are either providing steady power flows (such as coal, nuclear or run-of-river hydro power plants) or then they are mostly controllable (such as gas fired power plants or hydropower from dammed water pools). With that mix of inputs, electricity on demand becomes possible for most advanced economies. Additions of wind and solar power over the last decade introduced renewable electricity generation technologies into the grid. Those two sources have none of the above qualities: they neither provide steady flows, nor are they controllable. "No wind" means "no power", so does "no sunshine”, and even sharing across long-distances using high voltage DC (HVDC) transmission lines won’t change that fact, due to the stochastic nature of the inputs. Potentially crippling power outages will happen regularly in societies that rely on large percentages of these technologies to meet their electricity demand. With that, the current system of just-in-time electricity delivery would be replaced by one with irregular service interruptions. And yet there are plans made worldwide suggesting that we can produce 20, 30 or 50% of our future electricity consumption from those two sources. This is self-deception at best, and a lie at worst, as it is simply impossible to manage delivery systems where both inputs and outputs are largely uncontrollable, irrespective of other features added.

What is important here: we’re not talking about a future where renewable energies supplement fossil fuel based electricity systems like they do today. Given sufficient backup generation systems powered by fossil fuels, a larger penetration of renewable electricity is definitely possible, and might reduce carbon dioxide production and other externalities, albeit at a horribly high cost. However, these types of add-in systems fail to break our dependence on fossil fuels and don’t prove that we can deliver stable electricity in a world where renewable sources supply a majority of inputs into electricity grids. If that was the objective, we should be honest and just build some wind turbines and match them with gas fired generation capacity for low-wind times, instead of talking about long distance transmission, smart grids, and other technologies that despite their cost don't have the potential to secure the basic objective: stable power at any time.

Someone in the renewable electricity world would probably argue that this is where storage can play an important role. Unfortunately, again, this is more self-deception. Right now, storage that balances renewable sources comes from the flexibility of other stock-based supplies, such as natural gas and hydropower. They can be turned off when the wind blows, and turned on when it stops. The reason why this works is because renewables have such a small market share and often use much larger backup systems. Denmark for example operates its heavily wind-based electricity system with the backing of comparably huge hydro power plants in Norway and Sweden, an approach which unfortunately isn't scalable globally. Not many countries have neighbors with flexible energy generation capacity ten times their own, and that is about what is needed to buffer the huge long-term variability of renewable electricity generation.

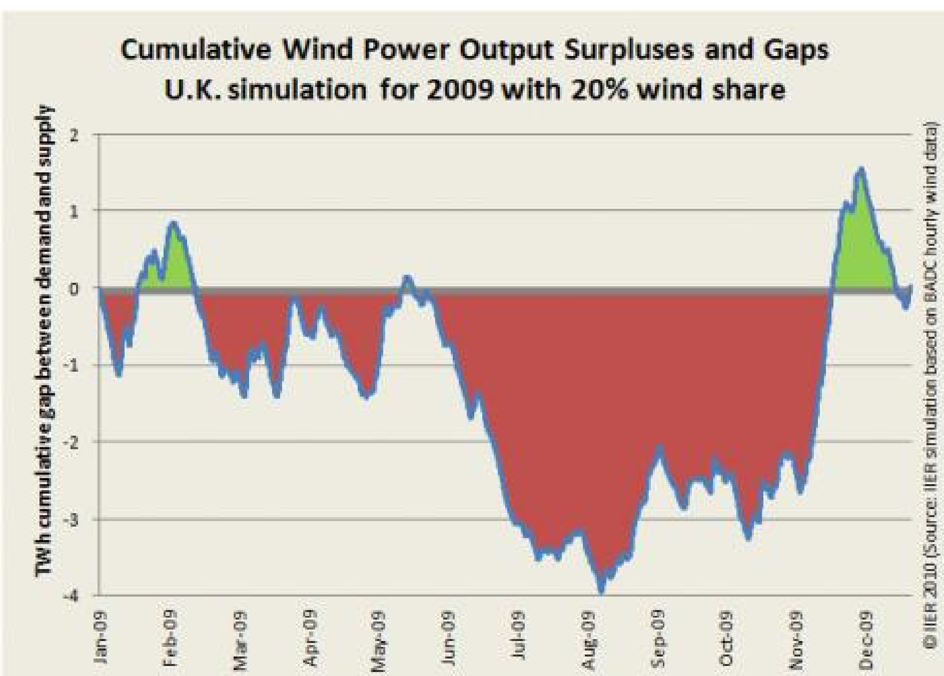

Fig 5: Annualized gaps and surpluses from wind (UK simulation)

So let’s for a minute assume that the United Kingdom - one of the world's "best" places to generate electricity from wind - runs on 20% wind power as planned in the least ambitious scenarios currently promoted, and that standby natural gas power plants become no longer available to bridge supply gaps. Some say that ELVs (electric cars) could provide the necessary storage capacity. We did the maths: the total annual output from wind in a 20% scenario for England and Wales would amount to approximately 64 TWh (20% of total current demand). After modeling a nationwide wind turbine network using the best 50 locations (we even included Scotland), we calculated the necessary storage to bridge the largest possible supply gap (e.g. when the wind doesn't blow for a number of days) and found that Britain in 2009 would have needed **96.5 million battery operated electric cars** with 40 kWh batteries each fully available for storage, e.g. no longer ready to be driven. For comparison: 28.5 million private vehicles are currently registered in the UK. The problem here is that wind patterns don't just include short term ups and downs, but instead do involve long periods with very little wind, and then long periods with a lot. Unfortunately, this pattern isn't even predictable year-over-year. Buffering those resources is not something that can be managed with storage, no matter how large. Another fake fireman.

The truth about electricity is simple, surprising and daunting: with the most promising renewable technologies - wind and solar - irrespective of expensive supplements being added, electricity systems as we know them today will not be able to operate. But instead of putting efforts towards finding real solutions, we are spending billions, likely even trillions, of dollars and Euros on technologies that cannot and will not work in the way we expect them to. Again, as a reminder: this is not an argument to defend the way we currently produce electricity, but a strong encouragement to research how we might get reliable power to our ubiquitous sockets without fossil fuels providing the major part. And for those who now suggest to go for a nuclear option: irrespective of any argument about long-term risk, this technology too has a number of downsides, among them the inability to control output according to demand, relatively high cost, and a high dependence on fossil fuels both for the construction of plants and the mining of uranium. And last, but not least, the fact that uranium too, is a non-renewable resources, subject to the fact that we will eventually arrive at the limits of meaningfully extractable material (e.g. the ones offering an attractive RREI) - particularly if we plan on scaling up nuclear power to replace other fuels.

Combustion fuels – headaches all over

The other big challenge ahead lies in fuels used for transportation and heating, mainly in oil. This is the place where scarcity is most apparent, as described above. We wouldn't try to drill in deep water or extract oil from shales if it wasn't for the inability to find and explore easier and cheaper sources. What this has done, at a minimum, is lifted the cost of oil to above 70 US$ a barrel, about three times its inflation-adjusted long-term average price. This is not because of speculation, as some claim, but just because it costs 60-70 US$ to extract those least attractive sources. Thus, we truly have to start thinking about alternative ways to move our cars, trucks, planes and even tractors.

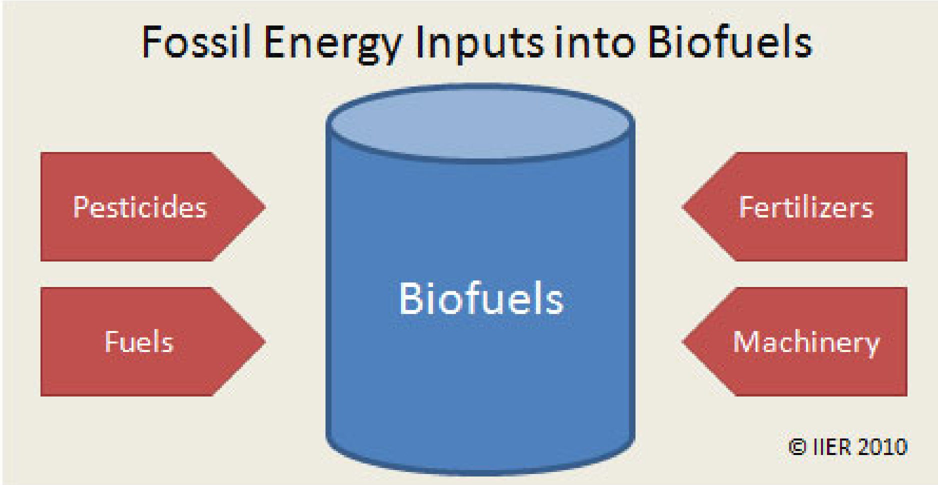

Fig 6. Fossil fuel inputs into Biofuels

The easy way out would be electric vehicles, but after reading the above paragraph on electricity, this might not be an entirely safe bet. And that doesn't even take into account the still existing technology and cost problems with battery technology.

One of the many challenges of a number of renewable energy technologies is that they are themselves heavily dependent on fossil fuel inputs. This is true for raw material extraction and manufacturing of solar panels, wind turbines and other things, but even more so for many so called “green” fuels. Significant inputs to the production process of biofuels - for example of corn based ethanol - come in the form of oil (fuels, pesticides), coal (electricity) or natural gas (fertilizer). This has two consequences: first, it doesn't break our dependence from fossil fuels and second, as fossil fuels become more expensive, so do these "alternatives".

However, one of the biggest challenges of all renewable (green) fuels is their limited availability. There simply isn't enough biomass potential in any Western society to produce a sufficient amount of non-fossil combustion fuels that could meaningfully replace what fossil fuels we use.

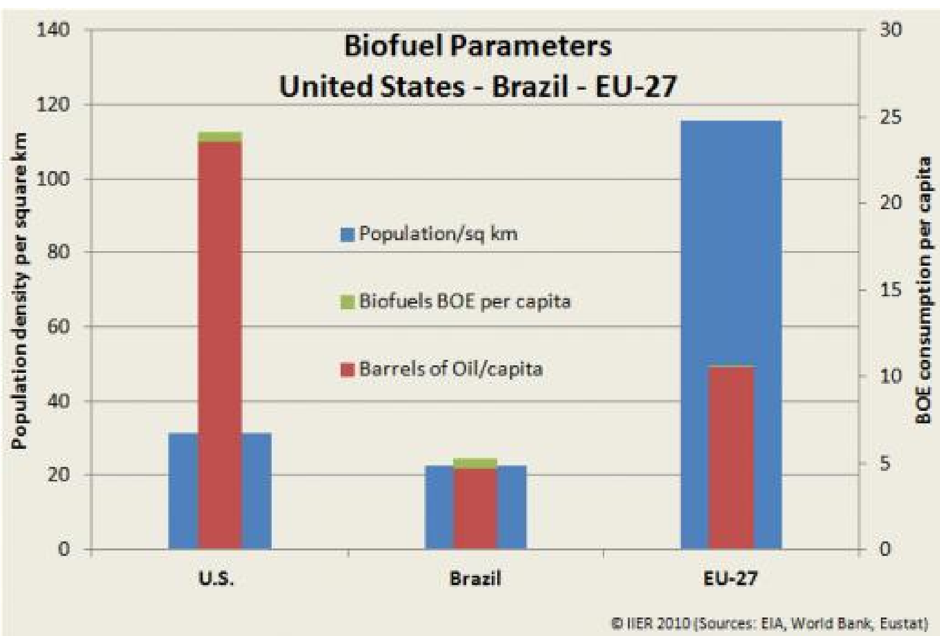

Fig 7: Biofuel parameter comparison

Brazil, which is often used as the poster-child of biofuels production and use, provides a stark reminder that building an oil-independent society with biomass-based transportation fuels is nothing but a dream. In 2008, Brazil produced (and mostly consumed) approximately 163.5 million barrels of ethanol. In the same year, the country consumed 907 million barrels of crude oil. Given the lower energy content in ethanol (3.53 MBtu per barrel vs. 5.8 MBtu for oil), biofuels had a share of not more than 9.9% of the two, while crude oil provided 90.1% of the total energy in liquid fuels. So much for Brazil running on renewable biomass. But that is just the beginning: when taking into account that Brazil is an emerging economy, and one of the least densely populated countries, the problem becomes even more obvious. With approximately 0.51 BOE (barrels of oil equivalent) per capita, the U.S. produced about exactly as much biofuel per person as Brazil did (0.52 BOE/capita). The only difference was that overall consumption of oil and biofuels together was 4.6 times larger in the U.S. when compared to Brazil, and twice as large in Europe (EU-27). Europe however, has yet another handicap limiting its ability to go for biomass. It has about 3.6 times as many people per square kilometer than the U.S., and about 5 times as many as Brazil, which constrains the continent's ability to grow enough biomass for biofuels and feed all its people at the same time.

So in a nutshell, there is no such thing as a replacement for fossil liquids coming from biofuels, instead this is just one more of those fake fire brigades.

A true plan for the future – begin from the other end

All of today’s planning efforts take place based on today’s energy delivery systems. We add some renewables to the current mix and see how we can manage. When we see that this causes problems, we respond by adding highly complex and costly bells and whistles. Alternatively, we start introducing new technologies that will never be able to truly scale up, are in fact heavily dependent on fossil fuel inputs, or both. We would go so far as to say that we can safely prove that more than 90% of energy system alternatives discussed and introduced today have no potential of helping us to secure a longer term energy future.

We are thus not sure if it is a good idea to put all of society’s efforts into fixes and add-ons to today’s energy delivery and consumption systems, but instead we strongly recommend the development of approaches and technologies that radically break with a fossil fuel base. The only meaningful way of looking at the future of energy delivery and application technologies would be to build energy systems based on an assumption that renewable technologies have to provide the entire amount required by our societies, and then to reshape societies so they are in line with what and how these technologies can deliver.

Only when applying this (what is probably considered radical) view, we would be able to model a sustainable and reliable energy future. Once we have figured out how this can work, we may still consider how to make the best use of our remaining fossil fuels, but going the other way will just fool us into believing that we have solutions, until we recognize we don't. And today, to be frank, this is exactly where we are. A lot of fake firemen are standing around a fire that is right now openly breaking out.

IIER puts substantial effort into trying to understand what energy systems could work in the long run. But unfortunately, very few other people do so, which is something we want to change. Instead of spending billions or even trillions on amendments that most likely won't help, a significant portion of these investments should go into a completely new design of our energy future. Let's finally bring in the real fire brigade.

Read Part II: Revisiting the Fake Fire Brigade - General Issues

Read Part III:Biomass - A Panacea?

Read Part IV: The Biggest Part of Business as Usual - Electricity

Read Part V: Delivering Stable Electricity

Resources and links

Link - An impressive review of past presidents' committments regarding the U.S. energy future, by comedian Jon Stewart