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Scientific American's Path to Sustainability: Let's Think about the Details

Posted by Gail the Actuary on November 9, 2009 - 10:10am
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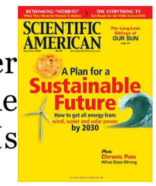

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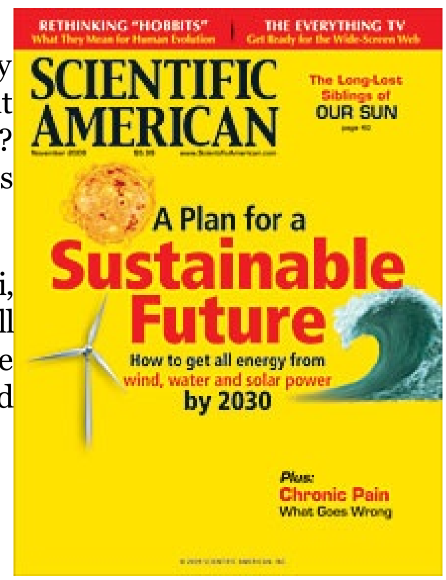

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The authors of the article, Mark Jacobson and Mark Delucchi, propose substituting wind, water, and solar (WWS) energy for all other forms of energy by 2030, not for just the US, but for the world. The types of energy sources that would be eliminated include the following:

• Petroelum (including gasoline, diesel, propane, heating oil, etc.)
• Natural gas
• Coal
• Liquid biofuels, such as ethanol
• Wood and other biomass
• Nuclear

All that would remain would be wind, wave power, tidal energy, hydroelectric, geothermal, and solar. Because of the ambitious timeframe, the only techniques that can be used are ones that work at large scale today, or are very close to working.

What would we end up with?

Essentially, we would need to change all of the world's infrastructure to use either electricity or solar or water power directly--by 2030. What might this mean?

• **Airplanes.** The authors propose that airplanes be powered by hydrogen powered fuel cells (with the hydrogen be made by hydrolysis using WWS energy sources). I understand that hydrogen is three times as bulky as gasoline, explodes easily, and escapes fairly quickly from its holding tanks, making it difficult to store for very long. It seems like airplanes and helicopters would need to look more like blimps, to hold the necessary fuel. Unless the explosion issue is solved, the popularity of hydrogen fuel cells would likely be pretty low.

• **Ships.** The authors don't tell us how ships would be powered. Clearly sailing ships would meet the criteria, but would be quite slow. Because of their slow time for passage, we would need a lot more sailing ships than the types of ships we use now, because so many would be in transit at a given time. Barges could float down rivers, and if the current isn't too strong, could perhaps be towed back in some way (boat with fuel cell?). Ships powered by hydrogen fuel cells might also work, but they would have the same issues as for airplanes. Because of their long trips, leakage would be more of an issue than on airplanes.

• **Automobiles and Trucks.** According to the authors, these would be powered by batteries or hydrogen powered fuel cells. There are several issues--the technology is only barely there for automobiles and trucks--for example, I don't know of anyone working on battery-powered technology for long distance trucking. Fuel cell technology is very expensive. David Strahan in The Last Oil Shock says that the current cost is about $1 million dollars per car. He quotes the chief engineer at Honda as saying it would take 10 years to get the cost down to $100,000 a car.

Minerals shortages are also likely to be a problem for converting autos and trucks to batteries or to hydrogen fuel cells. The Scientific American article mentions following materials as being in short supply: rare-earth metals for electric motors, lithium for lithium-ion batteries and platinum for fuel cells. The article mentions recycling as a partial solution. Analyses published at The Oil Drum, such as this one, indicate that we would likely run out of rare materials fairly quickly, even with recycling.

• **Farm equipment; bulldozers; cement mixers; and other heavy equipment.** Would need to be converted to electric. It is not clear that the technology (or rare materials needed for the technology) exist to do so.

• **Heating of buildings; heating for cooking and baking; hot water heating; commercial heating; heating of grains to remove excess moisture.** Would need to be converted to electric, or in some cases solar. This would be true, even where heating is now done over wood or charcoal fires, such as in Africa or China.

• **Mining and manufacturing.** Would need to be converted to all electric. Presumably oil and natural gas extraction would continue, but at possibly lower rates, because of their uses for non-energy uses, such as textiles, asphalt, plastics and lubrication. Drilling for oil and gas would be converted to electric as well.

What steps would be needed to build all of these things?

It seems like we would first need to figure out what the end point would look like, and then work backwards.

We are told that the authors of the Scientific American article think we would need the following:

• 3.8 million large wind turbines

• 90,000 solar electricity generating plants

• "Numerous geothermal, tidal, and rooftop photovoltaic installations"

Besides these, we would need to build all of the new airplanes, ships, cars, trucks, heavy equipment, and new appliances that would be needed under the new regime. Individual homeowners would need to get their homes rewired for the larger amount of electricity they would use--especially if they are converting to electric home heating.

One thing we need to plan for is a greatly expanded and improved electrical grid. The Scientific American article indicates that the variability in generation would be mostly smoothed out by combining electrical transmission of many different types--wind, hydroelectric, solar, geothermal, and wave--over a wide geographical area. To do this will require considerable long distance transmission, often between different countries--including some that may not be friendly with each other. The grid will also need to be upgraded to be "smart," so automobiles can draw electric power at the times of day when it is not needed elsewhere.

Once we have figured out what the new system will look like, we will need to figure out what kind of factories are needed to build all of the devices for the new system, and what raw materials the factories will need. Some of the raw materials can perhaps be obtained by recycling, and some factories can perhaps be obtained by converting other factories, but this won't always be the case. It is likely that new factories will need to be built, and new mines opened, especially for the rare minerals.

By the time we start seeing many finished good produced, it is likely that we will be at least half way through the 20 year period. In part, this is because we are still working out technology details (for example, how to efficiently build a hydrogen fuel cell powered airplane). Also, once we get those details worked out, we need to build mines for raw materials and build the factories to make the new devices. It is only when we get those steps taken care of that we can build what we really want--the airplanes, the new ships, the wind turbines, the solar PV, and all of the rest.

When sizing the factories, we will need to size them not for "normal" production levels, but for converting the economy quickly to use the new power sources. For example, under normal circumstances, if earth-moving equipment is expected to last for 40 years, we would expect to need factories to make 1/40 of the world's needed earth-moving equipment in a given year. But if we need to ramp up to replacement in 10 years, we will need 4 times as many factories. (What do we do with the excess factories at the end?)

How much would this all cost?

The authors tell us that they expect the cost of the new WWS energy generation equipment would be $100 trillion over 20 years. But that doesn't include the cost of all the new infrastructure to go with it--the new airplanes and ships and cars and trucks, or the electrical transmission lines. In total, the cost will be far higher than $100 trillion--lets guess $200 trillion--to be paid for over the next 20 years.

The Scientific American article gives the impression that the costs will be low, because it looks only at the cost the new electricity generation, and assumes that cost of generation will go down with volume and with additional research. It also implicitly assumes that debt financing over a long period, such as 40 years, will be used, so we don't have to pay for the cost of the new system before we start using it. But how realistic is that?

The cars, trucks, boats, airplanes, coal fired power plants, etc. we are currently using won't have much trade-in value once power is generated by WWS, and the new equipment will likely be fairly expensive. So we will be faced with buying new high priced equipment, with little trade-in value from what we used previously. In many cases, businesses would not normally be replacing equipment this soon. The debt that was taken on to pay for all of our current equipment won't magically go away either--it will still need to be paid.

So how will we pay for all of the new equipment? The governments of the world are pretty much maxed out for borrowing. Companies are not going to be able to take on a project of this magnitude either, especially since they already have debt to service. It seems to me that the only way a program such as the program of WWS fuels replacing other fuels can be financed is through increased taxes that would cover each year's expenditures, as they are made.

So let's think about how much this would cost. $200 trillion over 20 years amounts to $10 trillion a year, spread over world economies. The US share of this would be something around 21%, based on the ratio of US GDP to world GDP. So let's say that the US would need to fund $2.1 trillion a year. Let's compare this to current taxes. In 2008, US Federal, State, and Local taxes combined amounted to $4.1 trillion according to the US Bureau of Economic Analysis. In order to collect $2.1 trillion more, a tax increase equal to slightly more than 50% of all taxes currently paid would be required. If the additional tax were collected as a percentage of "personal income" (which includes wages, social security income, rents, dividends, etc.), it would amount to 17% of personal income. It seems unlikely that a tax of this magnitude, or even half of this magnitude, would be agreed to by tax payers.

If such a tax were passed, after a few years there would be benefits that would start offsetting its cost, and might lead to a lower tax, and after 2030, perhaps lower costs overall, because it is no longer necessary to purchase fossil fuels. The benefits that would start offsetting costs would be sales of electricity and other energy, and sales or leasing of vehicles and other goods produced. Many of the sales of goods would be going to replace automobiles that had worn out, factories beyond their useful life, and ships that no longer had value to the owners.

But there is a remaining issue. There will be a lot of assets which would still have considerable value in 2030, if it weren't for the new law. For example, a new car with an internal combustion engine that was manufactured in 2028 will still have considerable value, and a gas fired stove a homeowner owns will still have value, even though he needs to replace it with an electric one. A coal fired power plant built in 1980 is likely to still have value, apart from this law, and so will all of the tankers used for international transport of oil, and all of the natural gas pipelines. Should the owners of these assets be compensated for value of their otherwise-useful assets? There is nothing built into the tax to do so.

It would seem to me that these owners should be compensated, even if it takes a higher tax to do so. In part, this compensation could come in the form of "trade in" value, if a new automobile or electric stove or other item is purchased. But suppose the assets that lose value belong to businesses, and aren't easily traded in for corresponding asset--such as a coal fired power plant, or natural gas pipelines. I would argue that compensation for the remaining value of these is really needed as well.

The assets that will lose value because of the new law are typically owned by a company. The stocks and bonds of these companies will generally have a wide variety of owners--very often pension plans, insurance companies, endowment funds, and individuals saving for their retirements. If the otherwise-useful assets of these companies are taken without compensation, the companies are likely to default on their bonds, and the stocks of these companies will lose value. This will mean that some pension funds will not be able to pay their promised payments, and some life insurance policies will not pay as promised. If there is no compensation to these companies by a tax or some sort, the loss will flow through the system and hit others--with retirees likely hit the hardest. So there will be a loss to the system, one way or another.

How sustainable would this system be?

There are a number of weak areas in this system:

• There are not likely to be enough rare minerals (and even not-so-rare minerals), to make all of the desired high-tech end products. Recycling will help, but it is likely that the system will run into a bottleneck in not very many years.

• The system will use a huge number of electrical transmission lines. These transmission lines are subject to all kinds of disturbances--hurricane or other windstorm destruction, forest fires, land or snow slide, malicious destruction by those not happy for some reason (perhaps those unhappy by wealth disparities). Fixing lines that need repair will be challenging. We currently use helicopters and specialized equipment. These would need to be adequately adapted to a system without fossil fuels.

• If electricity is out in an area, pretty much all activity in an area will stop (except that powered by local PV), and there will be no back-up generators. Residents will not be able to recharge vehicles, so they will quickly become useless. Even vehicles coming into an area may get stranded for lack of recharge capability. Food deliveries and water may be a problem. The current system at least offers some options--back-up generators, and cars and trucks powered by petroleum that one can drive away.

• Operating the system will require a huge amount of international co-operation, because the transmission system will cross country lines. If one country becomes unable to pay its share, or fails to make repairs, it could be a problem.

• All of the high tech manufacturing will require considerable international co-operation and trade. This could be interrupted by debt defaults by major players, or by countries hoarding raw materials, or by difficulty in producing enough ships and airplanes to handle international trade.

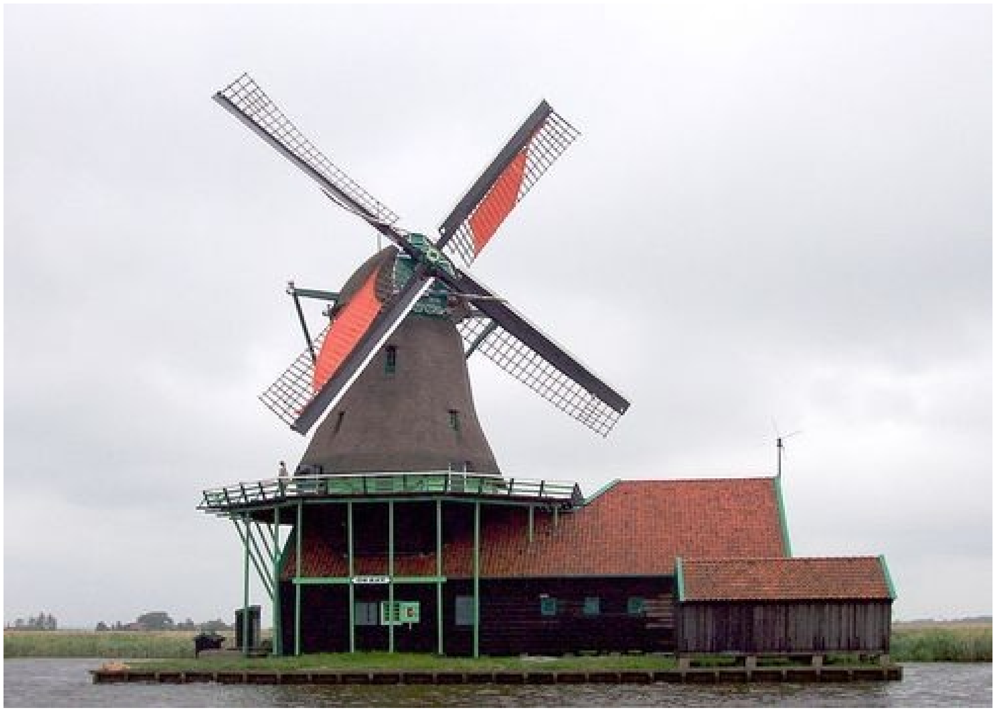
• The system clearly can't continue forever. It could be stopped by a lack of rare minerals, or international disputes, or lack of adequate international trade. The system doesn't provide any natural transition to a truly sustainable future. For example, food production is likely to still be done using industrial agriculture, with the food that is produced shipped to consumers a long distance away. It will be difficult to transition to a system which is truly sustainable at the point the system stops working.

What would a reasonable timeframe for transition be?

It seems to me that a reasonable timeframe for a transition such as that discussed in the Scientific American article would be 50 years, rather than 20 years suggested in the Scientific American article. With such a timeframe, there will be a little more time to fine tune technology, so as to find cost-efficient solutions that scale well. We also have more time to use the factories that are built, so that we don't have to overbuild, just to meet a deadline. Costs are likely to much easier to handle, since there will not be as much of an overlap issue. In addition, there will be much less problem of having to dispose of other-wise useful assets.

The problem is that we really don't have 50 years to make a transition. We already are on the downslope. We should have started back in the 1960s with a project like this.

It seems to me that all we can do is a very much reduced version of an approach such as the one described in the Scientific American article. Given the timing, we may not even want to do an approach such as described in the article. The approach described assumes a high level of international trade continuing long-term. This is a fairly optimistic assumption, given the difficulty of air and ship transportation without fossil fuels.



Instead of the high tech approach advocated by Scientific American, we may want to find solutions that can be done locally, with local materials. For example, we may want to encourage local agriculture. For industry, we may want to look at solutions that have worked in the past, such as wind powered factories, as discussed in this recent post. These were built with local materials, and were used to power factories directly, without conversion to electricity. With such solutions, a transition to a truly sustainable future will be much more of a possibility.