People's Summary of *Roadmap to Nowhere*:
The Myth of Powering the Nation with Renewable Energy
by Timothy Maloney and Mike Conley

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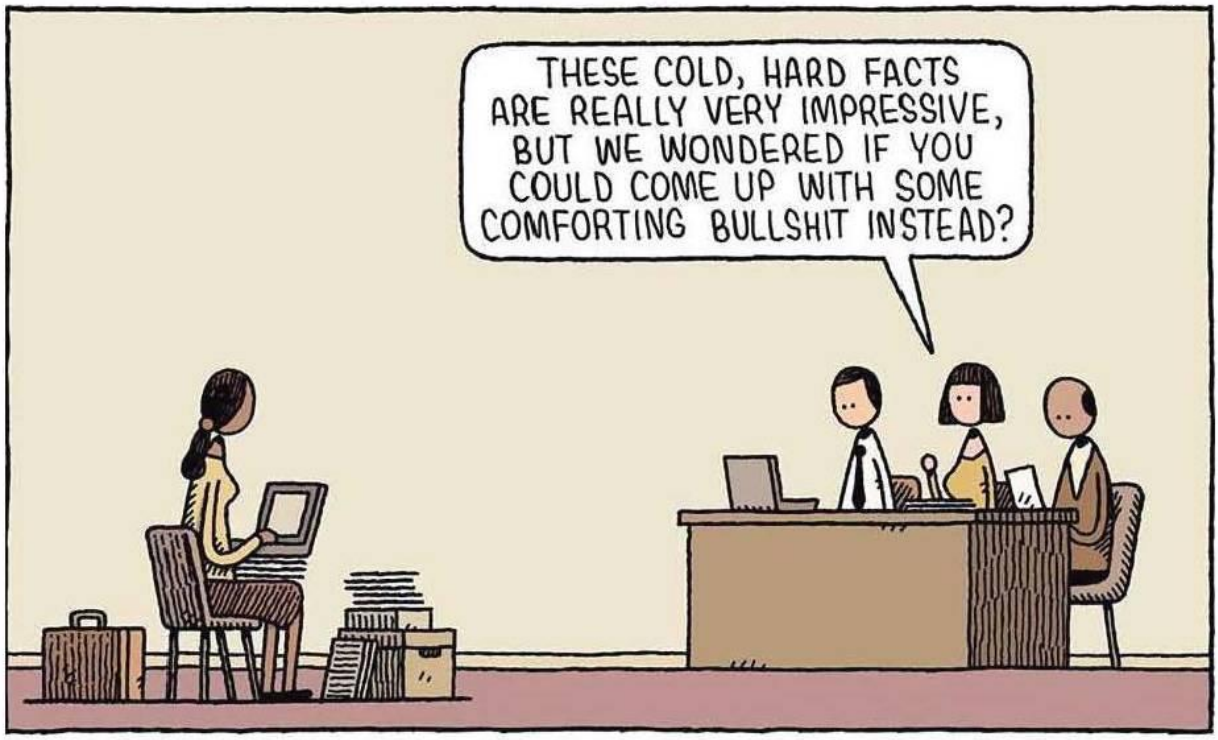

Climate change activists seeking alternatives to the burning of fossil fuels have been buoyed by the studies of Mark Jacobson and his colleagues at Stanford University, who have developed what they believe are feasible carbon-free energy plans[1] *for every US state and every nation around the world. Their plans envision replacing all fossil fuels with waterpower, wind power, and solar energy – the "100% renewable" or WWS model.*

There have been a number of critical responses to the work of Jacobson et al, including a strong critique[2] published in the Proceedings of the National Academies of Sciences. Two energy analysts in California, Timothy Maloney and Mike Conley, have prepared an extensive, highly readable critique of the WWS plans for the US[3], and there is a short video[4] presenting their case as well. Their text[5] is 145 pages in length, including hundreds of footnotes. What I have done here is to extract the key points which Maloney and Conley make, in their own words.

Everything here is in their own words. There is a lot more in their paper, including many interesting comments that greatly strengthen their case. I encourage readers to get their original text and read it.

ROADMAP TO NOWHERE

The Myth of Powering the Nation
With Renewable Energy

by

Mike Conley and Tim Maloney
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A commentary on the 2015 landmark paper:

100% Clean and Renewable Wind, Water, and Sunlight (WWS)
All-sector Energy Roadmaps for the 50 United States

by Mark Jacobson, Mark Delucchi, et al

(We read it so you don't have to.)

Renewables have captured the public's imagination,
but are they a realistic road to a sustainable future?
Or a soothing fairy tale that Mother Nature will provide
the energy we need if we gather her bounty?

This book will challenge everything you thought you knew about renewable energy.

The 50-State Roadmap has become the go-to bible for WWS advocates in any discussion of U.S. energy policy. Their goal is laudable – a clean, green global civilization by mid-century. Getting there is the problem. And replacing carbon-free nuclear power with renewables is not the solution.

This book shows you why.

The 132-page plan details the equipment required (solar panels, wind turbines, etc.) for each state's participation in the national strategy. The feasibility, resource availability, and practicality of the nationwide scheme are simply assumed.

While enthusiasm for the Roadmap is strong, we wonder if advocates have actually read the fine print, because the more you pencil it out the sketchier it seems. After reviewing the entire proposal, it's our conclusion that the Roadmap is deeply flawed. We'll show you exactly how and why.

This is more than an academic argument. The long-term energy plans of towns, cities and states are being actively shaped around this popular proposal and underwritten (for now) with

substantial state and federal incentives. So we all need to know if the proposal is sound. Particularly since the Roadmap has become a national meme, as if it were a well-proven, highly workable, ultimately affordable, and entirely do-able national project. Even though it's not.

Before the renewables fans who are reading this become too annoyed, we should clarify something right here and now:

We all want the same thing.

We all want enough carbon-free energy to power the planet, reduce pollution, reverse ocean acidification and mitigate Global Warming. We're on the same team.

Because we are, we feel obligated to explain to our fellow environmentalists in particular, and our fellow human beings in general, why it is highly unlikely that the Roadmap will take us where we need to go, especially in the time we have to act.

As appealing as it may seem at first blush, the Roadmap is, unfortunately, an expensive, complex, inefficient, and ultimately unworkable idea. If not in principle, then certainly in practice. It is our view that the Roadmap will get us nowhere fast.

In our view, the interest in large-scale renewable energy is the direct result of a misinformed aversion to nuclear power. In the absence of that hyper-inflated fear, renewables would never be seriously considered as a viable solution for powering the grid.

Since wind and solar are weather-dependent, how can we depend on them if we can't depend on the weather? Especially in a world of global warming, where storms will be wetter and wilder as the years roll on, as more heat energy is pumped into the oceans and atmosphere.

A clean-energy solution comes down to either renewables or nuclear. There will not be sufficient resources for both.

The main issues that concern us are:

- The intermittent nature of WWS systems
- The risk of relying on a fuel-free grid with no substantial backup
- The World War Two-scale mobilization lasting 35 years
- The wildly optimistic buildout schedule
- The eye-popping price tag

Mass energy storage plays a big role in most large-scale WWS strategies. Various scenarios range from powering the entire grid for 4 hours, up to an entire day. In contrast, the tiny amount of storage in the Roadmap would only provide the equivalent of around 1.5 hours of nationwide power consumption.

The basic strategy of a wind or solar farm is the same as any actual farm: Make hay while the sun shines, use what you need, then store the rest for later or sell it.

The Roadmap takes a different approach:

- If we build enough wind and solar farms in enough places, they should all be able to back each other up – when it's cloudy in one place, it'll be windy in another.
- With a nationwide network of interconnected wind and solar farms, we won't have to rely on mass quantities of energy storage, or backup from fueled power plants.
- Just in case, we can place a small amount of energy in storage, to be used for smoothing out the occasional unexpected peak loads.

At least, that's the plan.

The Roadmap omits mass storage (including only limited amounts of pumped storage) and assumes no backup – it assumes energy can be drawn from areas of the country where there is energy to those that don't have any, but it doesn't include the cost of the new high voltage direct current transmission lines that would be needed to make this energy transfer.

In a WWS-powered world, a reliable renewables grid (even a local one) would depend upon viable grid-scale batteries (which don't exist, and likely never will), or a nationwide network of tens of thousands of other wind and solar farms, with thousands of miles of new transmission corridors, to back each other up and deliver power to their local markets.

Being fifty miles from nowhere, wind and solar farms will need new connecting corridors to the main trunk (the actual grid.) Many of those corridors will have to run through private property. Lawsuits and eminent-domain battles will delay some projects for years.

It's already happening in Germany, where their state-sponsored buildout of wind and solar (*Energiewende*) is meeting vocal resistance from property owners, particularly in scenic regions. In our hyper-litigious American culture, drawn-out court battles could dwarf the estimated $1 Million per mile for the new wires and towers.

Our existing grid, with over 8,000 electric power plants is thought to be the largest and most complex machine in the world. The Roadmap proposes to grow the machine by nearly 7 times and expand its carrying capacity by 3.4 times – and the cost of this grid expansion is not included in our calculations or those of the Jacobson group.

The Roadmap has some token gigawatts of geothermal, tidal and wave power, but over 95% of its primary energy would come from:

- Onshore wind
- Offshore wind
- Utility-scale PV (photovoltaic) solar
- Residential rooftop PV solar
- Commercial / government rooftop PV solar
- Concentrated solar power (CSP) with overnight thermal storage

The 35-year Roadmap would entail manufacturing (or importing) and installing:

- 496,000 5-MW wind machines
- 18 billion square meters of PV panels
- 50,000-plus wind and solar farms
- 75 million residential rooftop systems
- 2.7 million commercial rooftop systems

This would be the largest construction project in world history. Just to stay on-track with the Roadmap's second 5-year portion (the period 2020–2025), we'll have to exceed our best year ever in PV panel production by almost 29 times, and our best year ever in wind turbine production by nearly 17 times, based on U.S. production totals for 2016.

The sheer scale of the project verges on fantasy:

- A half million giant 5-MW wind turbines on acreage equal to New York state, Pennsylvania, Vermont and New Hampshire, and in open sea regions equal to West Virginia
- Billions of solar panels on land equivalent to Maryland and Rhode Island
- Concentrated Solar Power (CSP) on land equivalent to Connecticut
- Rooftop solar on 75 million homes and nearly 3 million businesses

Note, too: The Roadmap's estimates of the required land use are one-fourth of what the federally-supported National Renewable Energy Laboratory estimates for onshore wind and one-half what it estimates for solar.

The Roadmap calls out the number of new solar farms: 48,753. New wind and solar farms for 2050 could amount to perhaps 53,600 large plants, plus an additional 1,364 CSP plants.

Here is how much of these now exist, how much the Roadmap would include when completed, and what all this would cost:
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	Current	Roadmap			
System	Nameplate Capacity (GW)		% of Output	Cost ($T)	% of Cost
Hydro Dams	28.7	47.9	3		
Utility PV	)	490	31	5.3	35
Residential PV	4.4 (all solar)	63	4	1.5	10
Commercial PV	)	51	3	0.8	6
Concentrated Solar Power	)	70	4	2.2	5
Onshore Wind	21.8	490	31	2.6	17
Offshore Wind		305	19	2.7	18
Geothermal, Wave	1.9	74	5		
Total	**76**	**1591**		**15.1**	

The bare-bones Roadmap (without sufficient backup or storage) will then cost at least $15 Trillion [Jacobson, Table 4, p. 245, agrees with this figure.]. 24 hours of energy storage could easily cost another $7.6 Trillion.

Residential solar is a big, fat waste of money (10% of the cost for just 4% of the output).

Consider, for comparison, generating all U.S. primary energy by 2050 with nuclear power:

- Land equal to half of Long Island (including full security perimeters)
- $6.7 Trillion with current (Generation III) AP reactors (based on South Korea's price for U.A.E.)
- $3 Trillion with Generation IV Molten Salt Reactors
- Existing hydroelectric dams (upgraded to 3% of grid)
- Existing pumped hydro (to match the Roadmap, but superfluous)
- 18 months (minimum) of all-grid storage, in the form of reactor fuel

We contend that the overblown fear of radiation and contamination – and the overblown costs that result – are the main reasons why this self-evident solution isn't being pursued.

We'll be comparing an all-nuclear grid with an all-renewables grid, each grid totaling 1,515 GWs of new-build power plants. An all-nuclear grid would cost somewhere between $3 Trillion and $6.7 Trillion, using data from South Korea's current buildup of nuclear reactors. That's also the estimated price per watt of our favorite reactor the Generation IV MSR (Molten Salt Reactor).

While the Generation III+ advanced passive reactor is the best of its class, Gen IV reactors are the future of nuclear power. We're especially impressed with the Molten Salt Reactor (MSR), one of eight Gen IV designs now being developed. A peer-reviewed energy innovation study shows that five of the eight designs will be as cheap or cheaper than an AP, two of them substantially so. Gen IV reactors won't need water cooling, so they can be placed anywhere, not just along bodies of water.

The two cheapest reactors in the study have a construction cost of right around $1.20 per watt. And according to ThorCon, an American MSR company, their manufacturing (construction) cost for molten salt reactors will be $1.20 a watt. "A big shipyard . . . could easily manufacture 100 one-GW-e ThorCons per year." So two big shipyards = 200 GWavg annually. Therefore 1,515 GW ÷ 200 GW / year = 7.6 years.

In the wake of Three Mile Island, Chernobyl, 9/11 and Fukushima, the nuclear industry's excessive defense-in-depth approach to reactor construction has nearly priced their product out of the market. In fact, no other energy source is regulated anywhere *near* the standards that have been set for nuclear power, in spite of its superior safety and reliability. Indeed, living near a nuclear power plant subjects you to less radioactivity than eating one banana per week.

"Steel per megawatt" is a good yardstick: A megawatt peak of wind power requires nearly 8 times the steel of a megawatt peak of nuclear. But since wind typically has one-third the capacity factor of nuclear, the actual steel-per megawatt gap between the two technologies is more like 24 times.

And after all that, the Roadmap *still* doesn't pencil out. Like we said, we're not pro-nuclear, we're pro-math. (Actually, we're pro-nuclear *because* we're pro-math.) Go nuclear or go extinct.

[1] *http://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/WorldGridIntegration.pdf*

[2] *https://www.pnas.org/content/pnas/114/26/6722.full.pdf*

[3] *http://web.stanford.edu/group/efmh/jacobson/Articles/I/USStatesWWS.pdf*

[4] *https://www.youtube.com/watch?v=V2KNqluP8M0*

[5] *http://www.roadmaptonowhere.com/wp-content/uploads/2018/01/RTN-Jan-11-2018.compressed.pdf*