Wind and Solar's Achilles' Heel

The Methane Meltdown
at Porter Ranch

by
Mike Conley
&
Tim Maloney
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An excerpt from their upcoming e-book
"Let's Run the Numbers"

PART TWO

In which we use Maloney's First and Second Formulas to demonstrate the marginal utility of methane in the fight against global warming. (It ain't pretty . . .)

The bridge fuel to nowhere

Natural gas is touted as the carbon fuel that can help the world transition to a carbon-free energy paradigm, the friendly fossil fuel that's working its more unsavory relatives out of a job. The "bridge fuel" that can take us to a new world.

The big selling point of renewables is carbon-free power, but their big drawback is unreliability. To overcome this handicap, renewables need backup power, until that hoped-for day in the distant future when enough farms in enough regions produce enough excess energy to back each other up.

Coal is just as reliable as natural gas, but it's universally understood to be bad for our health[7] and bad for the environment. Coal plants are notorious for pumping out megatons of CO_2, along with a host of toxins like mercury, arsenic, cadmium, sulfur and lead. Carbon dioxide isn't a toxin, but just like drinking two gallons of water in one sitting, too much of a good thing isn't a good idea.

Nuclear is even more reliable than coal, and it's carbon-free, but renewable energy fans are convinced that in spite of its many advantages, nuclear comes with its own special kind of awful.

We beg to differ. While contamination is serious stuff, fear and paranoia are the two most common forms of radiation sickness.[8] (For a layman's overview of nuclear power, see: *Power to the Planet* [9]*,* and *Thorium Nuclear Slideshow.*[10])

Hydroelectric is reliable and carbon-free, but in the last century alone hundreds of thousands have died from dam failures[11] and millions more were displaced by dam construction.[12] Aside from those two drawbacks, hydro also has a built-in limit to growth: You can't build more rivers. So that leaves methane.

But methane is such a potent greenhouse gas that even a tiny leak can make a gas-backed wind or solar farm just as bad – *or worse* – than a coal plant, when it comes to global warming. But at least renewables farms don't kick out toxins . . .

Unless you count all the toxins involved in manufacturing solar panels,[13] or the environmental horrors of mining neodymium for wind turbine generators.[14]

"Natural gas. It's hot stuff."

That's what the GE ads keep telling us. And their new gas turbines are mighty impressive beasts. The 7HA "Harriet" is huge, efficient, and relatively cheap, a state-of-the-art behemoth that can be delivered by rail and configured as a "CCGT." (Combined-Cycle Gas Turbine: A large turbine that burns methane to produce power, combined with a steam turbine to generate more power from its hot exhaust, boosting total fuel efficiency.)

A complete CCGT power plant with two Harriets was just built in Pennsylvania for $592 Million, delivering 1,029 MW of baseload power. That's 57¢ per "installed watt," meaning the price per watt of something that generates X amount of watts.[15]

In the U.S., a new coal plant installs for about $2 a watt. And that's a regular coal plant, not a "clean coal" plant (which, many will argue, is a contradiction in terms.) A Generation-IV Molten Salt Reactor is predicted to cost even less than a regular coal plant.[16] But even so, they won't be as cheap as a CCGT system.

Gas turbines can't be beat when it comes to the price per installed watt, and that's one big reason why America's shale oil and gas industry is enjoying a massive expansion. The holy grail of domestic energy independence finally seems to be in reach, thanks to methane, the not-so-awful bridge fuel that can take us to a clean, green future.

The renewables master plan goes something like this:

If we just keep building lots and lots of wind and solar farms with methane training wheels, we'll eventually have a nationwide interdependent network of renewable power plants. And if we overbuild the farms by 3X or more, they'll produce enough excess energy to back each other up, and we can even drop the training wheels. Problem solved! (Adios, Mr. Methane, and thanks for the help :)

But there's a catch . . .

Any gas is an escape artist, and methane is no exception. And with such a strong GWP (Global Warming Potential), a leaky infrastructure can easily cancel whatever green energy advantage a gas-backed renewables farm, or a gas power plant, is supposed to provide.

Like we said, natural gas is about 90% methane, and methane (CH_4) is a tiny little critter – a carbon atom with four hydrogen atoms attached. In spite of its size, the molecule punches far above its weight: Pound for pound (actually, we'll be calculating in kilograms) methane has 84X the GWP of CO_2. But if it makes you feel any better, it mellows out to "only" 28X after the first 20 years.[17]

> **Nerd notes:**
>
> Technically, a CO_2 molecule has more *mass* than a CH_4 molecule, as distinct from more *weight*. Weight is the pull of gravity on mass, which is why the stuff we send to Mars weighs less there than it does on Earth. That's why scientists prefer to use mass instead of weight. But since our calculations are for the same planet, we'd rather use the more common term.
>
> Sometimes you'll see a GWP of 86X for methane, instead of 84. Here's why: When it floats around in the atmosphere retaining infrared energy (heat), the global warming that methane causes will also cause the planet's natural carbon sinks to absorb less carbon dioxide from the atmosphere. "Carbon sinks" are things that absorb CO_2, such as the oceans and land-based plant life, and the warmer it is the less efficient the sinks are. This add-on effect raises methane's GWP from 84 to 86X, but we'll be using the more conservative number.

"Infrared energy" is the heat that radiates from the earth's surface after it's been warmed by the sun. "Greenhouse gases" in the atmosphere capture and retain this energy. Some do it more effectively than others, and different gases do their thing for different lengths of time. Carbon dioxide remains active in the atmosphere for centuries, but in the short term methane is far more powerful.

And the short term may be all the time we have to prevent the worst of global warming. Since the Arctic is warming faster than the rest of the planet, the billions of tons of methane hydrate frozen in the ocean and in Arctic lakes ("calthrate ice") is starting to bubble to the surface, and the permafrost is leaking methane as well.[18] So if you think a leaking gas pipe is a problem, just wait . . .

But getting back to the here and now: The problem with fugitive methane is that any wind or solar farm backed by gas, or any stand-alone gas power plant, will exceed its Worth-It Threshold if the well-to-wheels infrastructure supplying fuel to the turbine leaks by more than a few percent.

The "well-to-wheels infrastructure" is an oil industry term that covers everything from the well in the field to the spinning wheels of a vehicle, including electric vehicles charged by fossil-fuel power plants. The term encompasses the wellhead, the pipeline, railcars, trucks, storage tanks, service stations, vehicle gas tanks – the works. Whatever's needed to get the stuff out of the ground and into a combustion chamber. And any of them can leak, at any time.

Leakage

In the U.S., fugitive methane leaks range from 1 to 9%.[19] Modern-era leakage has more than doubled our atmospheric methane from an estimated pre-industrial 750 parts per billion to about 1,800 ppb today.[20]

And the leaks don't just come from operating wells. They can happen anywhere in the infrastructure.[21] The Aliso Canyon storage well in Porter Ranch is only one infamous example. Infamous but not unusual, because there are over 400[22] such storage sites in the U.S. under what's been termed "shoddy" supervision.[23]

Our formulas demonstrate that any gas infrastructure with a leak above 4% will render most gas-backed wind or solar farms, or state-of-the-art CCGT plants, as bad for global warming as a coal plant. And leaks approaching 8% will make even the highest-performing wind farms a threat to the climate as well.

One disaster like Porter Ranch, and there goes an entire region's green energy goals, for months or years on end. Switching to methane for cleaner power generation, or using it to back up renewables, can end up being little more than a feel-good gesture, like bailing out the Titanic with a coffee cup.

Scrupulously maintaining the integrity of an entire national methane infrastructure is hard enough as it is. But banking on it as a bridge to a clean, green world could be riskier than betting the farm. We could be betting the planet.

But wait! There's less!

Remember how we said that burning methane for energy produces about half the CO_2 of coal? *About* was the operative word in that sentence, because "simple-cycle peakers" are much less energy efficient than the big CCGTs.

"Peaker" is industry slang for a simple-cycle gas turbine, meaning there's no combined-cycle steam system to exploit its hot exhaust. A peaker can be quickly started and ramped up (accelerated) to top speed, and just as quickly ramped back down to idle mode, or powered off until it's needed again.

The term comes from using these specially-built turbines to kick into action and ramp up, sometimes within minutes, to generate power for unexpected peak loads on the grid. Like, say, when there's a freeway chase with a dozen cop cars and helicopters, and everyone turns on their TV. No grid operators can anticipate stuff like that, so they have peakers on stand-by. Think of them as gas-guzzling hot rods, ready to burn rubber on a moment's notice.

A Combined-Cycle Gas Turbine, on the other hand, is like a fuel-efficient touring sedan on cruise control, a gas-sipper that's made for the long haul. They're built for comfort, they ain't built for speed. CCGTs can take hours to ramp up to full power, and then they can hum along like that for months on end.

Unfortunately, the gas-guzzling peakers are the only kind of turbines nimble enough to back up the variable energy of wind and solar. If a CCGT is used to back up a renewables farm, it's operated in simple-cycle mode, which essentially turns it into a big peaker – a Winnebago-sized sports car.

When operated as a true combined-cycle system, a cruise-control CCGT emits 45% of coal's CO_2, while a hot-rod peaker emits about 60%.[24] Which means that a typical peaker-backed wind or solar farm has the potential to exceed the Worth-It Threshold even easier than a stand-alone, fuel-efficient CCGT.

A few words before we begin

We used the best numbers we could find for the continental U.S. They might need to be adjusted for another country, or if further research alters any of the numbers we used. But in either case, the formulas themselves are entirely valid.

For example, burning U.S. coal to generate a megawatt-hour will, on average, emit about 900 kilograms of CO_2.[25] Some regions use cleaner coal and some use dirtier coal, but no biggie – just tweak the number and you're good to go.

As we said, the idea behind the formulas is very simple: We determine the best-case scenario, which is the "CO_2 avoided" by using methane instead of coal, and we divide that by the worst-case scenario, which is the "CO_2-equivalent" if all the methane we planned to use leaks before we can burn it as fuel.

Dividing the best case by the worst case gives us a leak percentage, which we call the Worth-It Threshold. Any leaks approaching or exceeding that threshold make the switch from a coal plant to a CCGT, or from a coal plant to gas-backed wind or solar, a useless gesture in the fight against global warming.

The Worth-It Threshold for any CCGT gas plant

Trigger warning: A little bit of math, but it's well worth it. Because instead of just taking our word for it, or buying into someone else's contrary opinion, you'll know exactly how we reached our rather sobering conclusions.

First, let's look at coal vs. a CCGT, using:

<u>Maloney's First Formula</u>

> *To generate one megawatt-hour with less Global Warming Potential than coal, the fugitive methane rate of the infrastructure fueling a CCGT plant must not exceed:*

$$(900 - 405) \div (84 \times 147) = 0.040 = \mathbf{4\%}$$

Relax! This is an easy formula. But go find a pencil, you'll need it. (We'll wait . . .)

Alrighty, then: First, look at the numbers on the left side of the formula, before the division sign. To produce one megawatt-hour (one megawatt of power for a period of one hour), a coal plant emits about 900 kgs (kilograms) of CO_2 (the exact emissions depend on coal quality.) To produce that same megawatt-hour, a methane-burning CCGT plant emits 45% of that, or 405 kgs of CO_2.

Now look at the numbers on the right side of the formula, between the division sign and the first equal sign. Methane has 84 times the GWP of CO_2, and a CCGT power plant burns 147 kgs of methane to generate one megawatt-hour. (Just like coal can vary in quality, the percent of methane in natural gas can vary as well, but it's usually around 90%.)

> **Let's click the pause button . . .**
>
> When the CCGT burns 147 kgs of methane, 405 kgs of CO_2 comes out the chimney . . .
>
> That seems like a discrepancy, doesn't it? Until you remember that we have to add oxygen from the atmosphere (an "air-fuel mixture") to burn the fuel. And oxygen weighs a lot more than the hydrogen in the methane molecule (CH_4.)
>
> When a CH_4 molecule goes into the turbine, it meets up with two oxygen molecules in the combustion chamber. O_2 molecules contain two oxygen atoms – they usually travel in pairs. This air-fuel mixture "combusts" (gets burned), causing the three molecules to break apart, which gives us nine individual atoms.

The carbon atom (C) from the methane links up with two of the oxygen atoms (O) to form one CO_2 molecule, while the four hydrogen atoms (H) from the methane link up with the other two oxygen atoms to form two molecules of water vapor (two H_2O's.)

Forming these three new molecules releases a *lot* more energy than the heat that broke the old ones apart, which is called an "exothermic" reaction. Exploiting the heat in carbon fuel is the science trick that changed the world.

So there you have it, as simple as Tinker Toys: One methane molecule goes in, combusts with air, new molecules are formed and energy is produced. And one carbon dioxide molecule comes out the chimney, along with two water molecules. But for our purposes, just follow the carbon:

One carbon atom goes into the combustion chamber with four hydrogen atoms attached (CH_4), and comes out with two oxygen atoms attached (CO_2). And since oxygen is much heavier than hydrogen, the CO_2 molecule winds up being much heavier than the CH_4 molecule that went in – 2.75X heavier, to be exact.

And that's why you emit 405 kilograms of CO_2 when you burn 147 kilograms of methane, because 147 × 2.75 = 405.

Back to the left side: Why do we subtract the 405 kgs of CO_2 from the 900 kgs of CO_2? Because that gives us the amount of CO_2 that we *didn't* put in the atmosphere by burning methane instead of burning coal. Which is the main reason we want to switch to a cleaner fuel – to avoid emitting so much CO_2.

So here's the calculation: 900 − 405 = 495 kgs of *CO_2 avoided* by using methane. That's our "best-case scenario": We avoided all that CO_2 by switching from coal to methane. Keep the 495 for the final step (we *told* you to get a pencil!)

On the right side, we have the GWP of methane, which is 84 times that of CO_2. And we multiply that by 147, which is the kgs of methane the CCGT needs to produce a megawatt-hour.

Why are we multiplying those together? Because we want to know how much CO_2 those 147 kgs of methane are equivalent to (global-warming-wise), if they all leaked out before we can use them as fuel.

So 84 × 147 kgs = 12,348 kgs of *CO_2 equivalent.* That's our "worst-case scenario": We switched to methane, and it all leaked out! Keep the 12,348 for the final step.

Dividing the best-case scenario (the CO_2 avoided) by the worst-case scenario (the CO_2-equivalent if all the methane leaked out) gives us the Worth-It Threshold for a CCGT:

495 ÷ 12,348 = 0.040 = ***4.0%***

Translation: To generate one megawatt-hour, 495 kgs of CO_2 emissions can be avoided by burning methane in a CCGT instead of burning coal in a coal plant. However, since methane has 84X the GWP of CO_2, the equivalent of 12,348 kgs of CO_2 will be emitted if all the methane needed to generate that megawatt-hour leaks from the gas infrastructure instead of being burned in the CCGT.

Bottom line: If the fugitive methane from a gas infrastructure averages more than 4%, then generating power with *any* CCGTs fueled by that gas infrastructure will cause more global warming than generating the same power with coal plants.

The Worth-It Threshold for any gas-backed renewables farm

Let's say your community is powered by a nasty old coal plant. A green energy company blows into town and proposes to replace it with a 1 GW (gigawatt) gas-backed solar farm: Sixteen million panels on 20 square miles of land (!) that will generate an average capacity of 23%. Which is a pretty good Capacity Factor (CF) for the American Southwest (we just decided you live in California.)

With a CF of 23%, this 1-GW farm will average 230 MW of solar energy over the course of a year, and a gas peaker will back it up with 770 MW for the full 1-GW rating. (Which means that it's actually a gas plant, augmented by solar. But anyway . . .)

So how do you decide if this multi-billion dollar investment would be a good move in the fight against global warming? All you need is three things:

The estimated CF of the solar farm, the fugitive methane rate of the gas infrastructure that would fuel the farm's turbine, and the following formula:

<u>Maloney's Second Formula</u>

> *Where CF is Capacity Factor, to generate one megawatt-hour with less Global Warming Potential than coal, the fugitive methane rate of the infrastructure fueling a simple-cycle gas turbine backing a renewables plant must not exceed:*

$$\{ 900 - [(1 - CF) \times 540] \} \div \{ 84 \times [(1 - CF) \times 196] \} = ?$$

We know, we know – it's more complex than the first formula. But you got through that one relatively intact, didn't you? This is what the numbers represent:

In the generation of a megawatt-hour, coal emits 900 kgs of CO_2, while a hot-rod peaker emits 540 kgs. The 84 of course is the GWP of methane, and 196 is the kgs of methane a peaker burns while generating a megawatt-hour.

Working the Second Formula

The way to do a formula like this is to work each side from the inside out, then do the final calculation with the numbers you got from each side.

The Capacity Factor of the proposed farm is 0.23, so starting on the inside of the left side, we do the ( ) part first: (1 − 0.23) = 0.77 (yes, you can use a calculator.)

Then we do the [ ] part: [0.77 × 540] = 416. And then we do the { } part: {900 − 416} = 484 kgs of *CO_2 avoided.* Save that number for the final step.

On the right side, we also start with the ( ) part: (1 − 0.23) = 0.77. Then we do the [ ] part: [0.77 × 196] = 151. And then the { } part: {84 × 151} = 12,684 of *CO_2 equivalent*.

Divide the left side by the right side to get the Worth-It Threshold.

Plugging in the farm's 0.23 Capacity Factor and doing the math, we get this:

484 ÷ 12,684 = 0.038 = ***3.8%***

Bottom line: If the methane leak rate of the gas infrastructure that will fuel the farm's turbine exceeds 3.8%, then you might as well just keep on burning coal for all the global warming good it'll do you. (Again, we're just talking global-warming-wise, not total-pollution-wise. Coal is a *lot* dirtier than methane.)

But all in all, the numbers are pretty pathetic, huh? Especially when some of the most recent measurements of fugitive methane in the U.S. are up to 9%.

Here's why the Second Formula works

Maloney's Second Formula compares generating a megawatt-hour (MW-hr) with a renewables farm backed by a peaker, versus generating a MW-hr with a coal plant.

In this example, it's a solar farm with a CF of 0.23. That means the panels produce, over the course of a year, an average of 23% of the full capacity of the farm, which is rated at one gigawatt (1 GW, or 1,000 megawatts.)

Let's start with the inside of the left half of the formula:

The (1 − 0.23) calculation gives us the percentage of power the peaker has to generate, to help the solar farm produce its advertised 1-GW output. With a 0.23 Capacity Factor, the peaker winds up doing 77% of the work: (1 − 0.23) = 0.77.

The 540 represents the kilograms of CO_2 emitted by a peaker generating one full MW-hr.[26] Remember, a simple-cycle peaker is a lot less fuel efficient than a CCGT, whose emissions per MW-hr are only 405 kgs of CO_2.

The [0.77 × 540] = 416 calculation gives us the kilograms of CO_2 the peaker emits while generating 0.77 MW-hrs.

Next, we do the { } calculation, where we subtract the peaker's emissions of 416 kgs of CO_2 while generating 0.77 MW-hrs, from coal's emissions of 900 kgs while generating an entire MW-hr: {900 − 416} = 484 kgs of *CO_2 avoided.*

Now why did we do that? At first blush, it looks like we're cheating. But think it through: We're comparing the emissions of the entire solar farm, versus the emissions of a coal plant, in the generation of one MW-hr. And just like we do in the First Formula, we're looking for the total amount of avoided CO_2.

Since the solar panels are producing 23% of the farm's power, the peaker's emissions come from generating the other 77%, *not* from generating the entire MW-hr. And since the solar panel energy is emissions-free, the "total emissions comparison" between the solar farm and a coal plant comes down to the solar farm's peaker emissions @ 0.77 MW-hrs vs. a coal plant's emissions @ 1 MW-hr.

So our best-case emissions scenario for a 1-GW solar farm with a 23% capacity factor is the CO_2 avoidance of its peaker combined with the zero CO_2 emissions of its panels, which comes to 484 kg / MW-hr.

Like the First Formula, the right side of the Second Formula determines the worst-case scenario: The CO_2-equivalent emissions if all the methane the peaker needs to generate 0.77 MW-hrs leaks out before it's used as fuel. Note that the solar panels would still be generating their carbon-free 0.23 MW-hrs, although the leak would wipe out the CO_2 avoidance of the panels. And then some.

On the right side, we also have the percentage of the solar farm's total energy that the peaker has to generate: (1 − 0.23) = 0.77. We multiply the 0.77 by 196[27], which is the kilograms of methane a peaker would use to generate a full MW-hr: [0.77 × 196] = 151 kgs. This gives us the methane a peaker burns to generate 0.77 MW-hrs.

In a worst-case scenario, all the methane would leak before we can use it as fuel. Since methane has 84X the GWP of CO_2, we do this calculation: {84 × 151} = 12,684 kgs of *CO_2-equivalent.*

And just like the First Formula, we divide the best-case scenario by the worst-case scenario to arrive at the Worth-It Threshold:

484 ÷ 12,684 = 0.038 = ***3.8%***.

Applying the Second Formula to the real world

You can determine the Worth-It Threshold for the peaker all by its lonesome.

Let's say it's nighttime. The solar panels aren't making any juice and the peaker's doing all the work. What leak rate would make the peaker as bad as coal? To find out, run the Second Formula with the Capacity Factor at zero. Answer: ***2.2%***

Pitiful. But let's say the CF of the solar farm is an impressive 30%. Answer: ***4.5%***

That's better. Let's try it at 40% CF. Answer: ***5.8%***

Pretty good. Now let's say you're living in Oklahoma, where the wind comes sweepin' down the plain, and you set up a wind farm where the CF is a mind-blowing 50%. What leak rate would make your ultra-high-performance 1-GW wind farm useless for fighting global warming? Answer: ***7.7%***

Granted, that's a substantial improvement, but all in all it's still a dicey proposition, considering the thorny issue of fugitive methane. Not a lot of wiggle room for a multi-billion dollar investment covering dozens of square miles, that could end up doing bupkis for clean energy.

This is especially true if long-term wind patterns shift or calm down – just two of the many consequences anticipated with climate change. And since the EROEI of a wind farm (Energy Returned On Energy Invested) is already so meager[28], relocating the farm to catch the wind would be totally out of the question.

And, since dismantling fees are rarely factored into the cost of a wind farm, yet another consequence of climate change may come to pass: Thousands of rusty, abandoned pinwheels the size of Boeing 747s littering the American landscape[29].

Three steps forward and one step back

The Aliso Canyon storage well in the Los Angeles suburb of Porter Ranch leaked for nearly four months, from October 23, 2015 till February 11, 2016. California's Air Resources Board (CARB) concluded that the leak totaled 94,000 metric tons, or 94 million kilograms. That's an average of 35,300 kgs / hr.[30] (Some sources say it's over 100 million kgs, but we'll use the conservative number from CARB.)

Before Porter Ranch, CARB determined that California's statewide infrastructure leak rate was 29,000 kgs / hr.[31] Which means Porter Ranch more than doubled the leak rate – *just like that.*

(29,000 + 35,300) = 64,300. (64,300 ÷ 29,000) = 2.2 times

We've determined that California's "ongoing" fugitive methane rate (meaning "without Porter Ranch") is already one-third of the way to the Worth-It Thresholds for the average gas-backed wind and solar farms, and for any CCGT power plants. No matter how well they perform, the state's leak rate is a handicap that wipes out a significant part of their green energy advantage.

But don't take our word for it. Let's run the numbers (get your pencil . . .)

A narrow margin of utility

The handicap imposed on any state's methane-generated electricity can be found by dividing the state's total methane leak by its total methane consumption.

Like we said, California's fugitive methane rate, without Porter Ranch, is 29,000 kilograms / hour. At 8,760 hours a year, that's: ***254 Million kgs methane / year.***

Now we have to find their total methane consumption. California's Energy Almanac tells us that in 2014, they used 121,934 GW-hrs of methane-generated electricity.[32] That's a good place to start, but there's no breakdown of how much power came from CCGTs and how much came from peakers, in their traditional role as fast responders to the sudden demands of the grid.

To be more than fair, we'll calculate a "weighted average" of fuel consumption, based on 80% CCGT generation and 20% peaker generation. If you recall, a CCGT uses 147 kgs of methane to generate a megawatt-hour, and a peaker uses 196 kgs. The 80 / 20 weighted average comes to: 156.8 kgs / MW-hr.

> (0.80 × 147) + (0.20 × 196) = 156.8

And since 1,000 megawatts equals one gigawatt, we multiply by 1,000 to get the fuel needed to generate one gigawatt-hour: 156,800 kgs methane / GW-hr.

To get the total methane consumption, we multiply the fuel rate by the amount of energy produced, and get: ***19.1 Billion kgs methane / year.***

> (156,800 kgs / GW-hr) × (121,934 GW-hrs generated) = 19.1 Billion kgs fuel / year

Now we have the two numbers we need: They're using 19.1 Billion kgs of methane / year to generate electricity, and they're leaking another 254 Million kgs / year (again, without factoring in Porter Ranch). Which means that California's ongoing statewide fugitive methane rate is: ***1.3%***

> 254 Million (leaked) ÷ 19.1 Billion (used) = 0.013 = 1.3%

That's a significant handicap for every gas-backed wind or solar farm, or CCGT, in the entire state: 1.3% is a bit more than one-third of a typical wind and solar farm's Worth-It Threshold of 3.8%, and a bit less than one-third of a CCGT's Worth-It Threshold of 4.0%.

And that's in a bellwether state at the forefront of renewable energy, with strict air quality standards and a lower leak rate than the rest of the nation.

If Porter Ranch leaked a total of 94 million kgs, and if California's yearly leak is another 254 million kgs, that's a grand total of 348 million kgs for the year. Which makes their leak rate, with Porter Ranch factored in, downright dismal: ***1.8%***

> 348 Million (leaked) ÷ 19.1 Billion (used) = 0.018 = 1.8%

That's almost halfway to the Worth-It Thresholds, which is a bad way to start the year. But now that Porter Ranch is plugged, just one-third of California's climate-saving efforts are going down the drain again, instead of almost half.

So everything's back to normal in the Golden State, which should calm the nerves of the anti-nuclear folks in Sacramento. Particularly since they placed all their bets on gas in the wake of Fukushima, and shut down the two reactors at San Onofre, which were generating more power than Hoover Dam.[33] They now intend to shut down the Diablo Canyon reactors as well.[34]

That's two Hoover Dam's worth of carbon-free power, one gone and one under threat. San Onofre was shuttered in January 2012, and by year's end, the final tally of California's methane consumption had jumped by 16%.[35]

It gets worse

As recently measured by the EPA, the nationwide fugitive methane rate averages 2.3%, with leaks ranging from 1% to 9%. NOAA reports some leaks at 4%, the University of Colorado reports that the Uinta Basin in Idaho is leaking at 9%, and a Cornell researcher says the total fugitive methane leak over the life of a typical gas well is 3.6 to 7.9%. In spite of these troubling reports, the gas industry assures us that the national average is 1.6%.[36]

So the numbers are all over the map. But even if we accept the industry's optimistic number, it imposes a handicap on every single gas-backed renewable farm or CCGT in the country. For the average farm or a CCGT, the handicap works out to around 40ish%:

$$(1.6 \div 3.8 = 0.42)\ (1.6 \div 4.0 = 0.40)$$

And that's *without* any Porter Ranch "meltdowns."

And as we mentioned, there are over 400 storage facilities like Porter Ranch scattered across the nation. Most are in rural areas, so they don't catch the public's attention. But Porter Ranch is a well-to-do community in one of the largest cities in the nation, a media hub with an environmentally conscious slant.

So now fugitive methane is a thing. Which is good – public awareness is the first step toward effective change. But even in the wake of the Porter Ranch disaster, most people still don't realize that it was the tip of a very large iceberg.

Everything's bigger in Texas

The Barnett Shale Formation in north-central Texas produces about 8% of America's methane, and is thought to be the largest onshore gas field in the nation. This underground treasure trove fans out westward from Dallas/Ft. Worth into the windswept prairie. The deposits of natural gas are held in "tight" geologic formations, but have now been unlocked with fracking technology. [37]

In spite of the industry's best efforts, Barnett has an ongoing leak rate of 76,000 kgs / hr. That's more than twice the average leak rate at Porter Ranch:

76,000 (Barnett leak / hr) ÷ 35,300 (Porter Ranch leak / hr) = ***2.15***

Even so, the ongoing Barnett leak isn't regarded as a disaster like Porter Ranch was. But that's because nobody really notices – the region is sparsely populated, and unlike the gas stored at Porter Ranch, methane doesn't come out of the ground scented with mercaptan. No, the Barnett leak is just the cost of doing business. Goes with the territory, like breaking eggs to make omelets . . .

Even though it's more than two Porter Ranches *that never gets plugged*. And if that sounds awful, it is. But that ain't the half of it. Not by a long shot.

From sea to shining sea

The yearly methane leak rate for the continental U.S. is estimated to be about 7.3 Billion kgs / year.[38] As you recall, the conservative estimate of the total leaked at Porter Ranch is 94 Million kgs. So we can make a rough calculation as follows:

7.3 Billion ÷ 94 Million = 77ish

Think of it: More than 70 Porter Ranches – unplugged and ongoing, all year long.

Which begs the question: If Porter Ranch was the worst environmental disaster since the 2010 Deepwater oil spill, what should we call this?

A faster, cleaner way to kill the planet

Using methane is a perfectly valid way to avoid the toxic emissions associated with coal, such as arsenic, lead, sulfuric acid, cadmium, etc. But if our main purpose in switching from coal to methane is to reduce greenhouse gases, or to use methane as the training wheels for wind and solar, the strategy is a flop.

Power generation has been driving the market for this leak-prone fuel, but the glory days may be coming to an end sooner rather than later: Several of our largest domestic gas fields have peaked.[39] And when gas fields peak, they decline a *lot* faster than oil fields. So even if all the foregoing wasn't true (and it is), our domestic energy boom may soon be going bust. And as we toboggan down the far side of the graph, the rise in price will be just as nerve-wracking.

Which, when the dust settles and the tears dry, might not be such a bad thing after all. Because with its sky-high GWP and its propensity to leak, methane is only marginally better than coal in the fight against global warming.

And for the few who still don't "believe"[40] in global warming, the question remains: Who wants to breathe all that gunk? Combustion was a great advance for power production 200 years ago, when the world had one billion people. But now we have over seven billion, with nine billion likely by mid-century, and we're still burning stuff for power.

To be perfectly blunt, fire is obsolete. So quite aside from the issues of global warming, or smog, soot, acid rain, lead, mercury, cadmium, asthma and emphysema (the list goes on and on), is combustion any way to power a planet?

Like the ads say, "Choosing energy is choosing the future."

The dispersed and intermittent energy of wind and solar is a natural handicap that can be minimized, but never eliminated. And as highly evolved as wind and solar technologies are, they still suffer from meager Energy Returned On Energy Invested.[41] Gas-turbine backup paints them into an even tighter corner, and the amount of land that wind and solar require is mind-boggling.

If we truly value our environment, then why in the world would we try to generate the power we need by industrializing nature? And then, once the damage is done, why compound the error every twenty years, by trampling those thousands of square miles of what used to be wilderness in order to replace millions of worn-out solar panels and tens of thousands of worn-out wind turbines?

Thus far, the best attempts by the green energy sector to mimic the output and reliability of coal, hydro, and nuclear have amounted to building gas plants with inefficient peaker turbines, augmented by windmills and solar panels.

The fundamental problem is, wind and solar companies have about as much control over the reliability of their methane supply as they have over the reliability of their two renewable fuels, the wind and the sun. Which is no control at all.

That's because the well-to-wheels methane infrastructure is controlled by an entirely different industry, with an entirely different set of priorities and market pressures. And as earnest as they are, the renewables industry can only be as clean as their suppliers' worst stretch of pipeline.

The future is now

We focused on methane's 20-year GWP because most people who are seriously concerned about global warming agree that the next 20 years, more than the next 100, is the critical time for action.

If that's truly the case, and if they're truly the environmentalists they claim to be, then perhaps they should re-think their choice of mass energy production systems. Because if global warming is actually happening, and if it's actually man-made, and if it's actually caused by excessive greenhouse gases, then the only sensible conclusion to be reached is this:

Methane isn't a bridge fuel to a greener world – it's a gangplank.

Footnotes

1. http://tinyurl.com/hhwmpzz
2. The term "renewable energy" is shorthand for "the energy produced with renewable fuels," since the supply of fuel (sunshine, wind, wave power, etc.) is constantly replenished by nature.
3. Topaz Solar Farm in San Luis Obispo, CA: http://tinyurl.com/zum2tjt
4. The Solutions Project (Jacobson, et al): http://tinyurl.com/h4vfkkq
5. Intergrating renewables on Gemany's grid: http://tinyurl.com/kyq6ddr (note Fig. 25 Interventions)
6. "Let's Run the Numbers" (Conley & Maloney): http://tinyurl.com/qheu5vu
7. Preventable Coal Deaths (Maloney): http://tinyurl.com/zsocyjf
8. "The Fukushima Disaster Wasn't Very Disastrous" (Conca): http://tinyurl.com/jnlqou6
9. *Power to the Planet* (Conley): http://tinyurl.com/z4hcea2
10. Thorium Nuclear Slideshow (Maloney): http://tinyurl.com/zvce3eh
11. Banqiao Dam failure: http://tinyurl.com/kfpz2df
12. 1,000,000 people displaced by Three Gorges: http://tinyurl.com/cwqtp83

13. "Solar Energy Isn't Always as Green as You Think" (IEEE Spectrum): http://tinyurl.com/my62j8g

14. "The Worst Place on Earth" (BBC): http://tinyurl.com/n3frxms

15. High-tech Harriet turbines (GE): http://tinyurl.com/js8fgbk

16. Thorium: Energy Cheaper Than Coal" (Hargraves): http://tinyurl.com/hkak3fx

17. 2013 IPCC report. For methane's GWP, see Chapter 8, page 58: http://tinyurl.com/oy64ct8

    In January 2013, the EDF used a GWP of 72X for methane: http://tinyurl.com/bypgtoy

    Later that year, they began using the IPCC's calculation of 84X: http://tinyurl.com/jchbnle

    See also: http://tinyurl.com/nz7x26e

18. Arctic Methane Emissions: http://tinyurl.com/jdwns5t

19. Fugitive methane measurements 1 to 9%:

    "Methane Leaks Erode Green Credentials of Natural Gas" (Nature): http://tinyurl.com/ax7lqjx

    "Air Sampling Reveals High Emissions From Gas Field" (Nature): http://tinyurl.com/87mjoxs

20. Atmospheric methane concentrations: http://tinyurl.com/pc2ldbh

21. Tracking fugitive methane leaks:
    http://tinyurl.com/h833srv
    http://tinyurl.com/hq7j6ke

22. 400+ underground methane storage sites: http://tinyurl.com/z2nxg5l

23. Supervision of methane storage (Reuters): http://tinyurl.com/zw8s8wn

24. Power plant emissions (U. of Colorado / NOAA): http://tinyurl.com/h9l799d

    As we mentioned, coal's emissions will vary depending on coal quality. To be more than fair, we went with 900 kgs / MW-hr, which is a bit below

CIRES' average of 915 for the 15-year period between 1997 and 2012 (see paragraph 5 of the linked article.)

Paragraph 5 also cites 436 grams per kilowatt-hour as the average CO_2 emissions of a CCGT for the years 1997–2012. That scales up to 436 kilograms per megawatt-hr, not the 405 kgs we used.

However, instead of using the 15-year average emissions rate of this evolving technology, we used the latest number available, which as you can see on the article's graph is significantly lower: The graph shows the 2012 emissions rate as slightly above 400 g / kW-hr. We "eyeballed" that spot on the graph as 405, and converted to kgs for MW-hr calculations.

25. *Ibid*: http://tinyurl.com/h9l799d

26. *Ibid*: http://tinyurl.com/h9l799d

27. Since CO_2 is 2.75X as massive as CH_4, 540 kgs of CO_2 emissions requires the combustion of 196 kgs of methane: 540 ÷ 2.75 = 196.

28. EROEI: http://tinyurl.com/p5do6aj http://tinyurl.com/h7k3fnx

29. Abandoned wind and solar farms: http://tinyurl.com/hvvcruy http://tinyurl.com/zsocyjf

30. http://tinyurl.com/got5r3d

31. California methane leak rate is 29,000 kgs / hr: http://tinyurl.com/zrb4suv

    The two middle bars (from oil & gas production and from pipelines) scale to 0.206 and 0.281 $MMTCO_2eq$ (million metric tons of CO_2 equivalent.) The two bars combined = 0.487 million tonnes of CO_2eq.

    CA Air Resources Board still uses factor of 25X GWP for methane over 100-year period, without climate carbon absorption diminishment (feedback):

    0.487 million tonnes of CO2eq ÷ 25 GWP = 19.5 million kg of CH_4 leaked in a 28-day period of Oct 23 - Nov 20. Therefore:

    (19.5 million kg ÷ 28 days) ÷ 24 hrs = 29,000 kg / hr CH_4 leakage rate.

32. California's methane-generated electricity in 2014: http://tinyurl.com/klx7k95

33. Hoover Dam: http://tinyurl.com/hjfvso7
    San Onofre: http://tinyurl.com/ckjgek9

Diablo Canyon: http://tinyurl.com/o75jfq2

34. Save Diablo Canyon: http://tinyurl.com/jcahysm

35. Energy in California: http://tinyurl.com/owa7u55

36. Fugitive methane emissions measurements: http://tinyurl.com/ax7lqjx

    See also: http://tinyurl.com/bypgtoy

    Note that in this article, EDF uses the GWP of 72X. As we point out in footnote 15, in November 2013 EDF began using the IPCC's GWP number of 84X, to conform with IPCC's AR-5 report from the summer of 2013:

    http://tinyurl.com/oy64ct8.

    Fugitive methane emissions in the shale gas (fracking) industry: http://tinyurl.com/pf6xobx

37. Barnett Shale: http://tinyurl.com/hq7j6ke

38. U.S. yearly leak total: http://tinyurl.com/jazm79x

39. U.S. gas fields are peaking: http://tinyurl.com/h2z72ng

40. Ahhhnold on climate change: http://tinyurl.com/qz3zkuz

41. EROEI of solar: http://tinyurl.com/h3uyt9s http://tinyurl.com/pc95wdq