Hold up! Keeping your gas furnace might be more environmentally beneficial than you think.



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I've been a frequent advocate for pursuing electrification for climate benefits, dating back to a talk I gave in 2014. I'm excited to see the rapid adoption of electrification policy objectives going on across the United States. The basic premise is solid, from my perspective:

1. Human-induced climate change will have giant impacts on our planet, causing all sorts of trouble for humanity.

2. Burning fossil fuels for heat and hot water in buildings produces a lot of greenhouse gas emissions that contribute to climate change.

3. We've figured out how to cost-effectively reduce carbon emissions from producing electricity.

4. Therefore, we should use low-carbon electricity for heat and hot water instead of burning fossil fuels.

However, in the recent work that I've been doing in Colorado, looking at the cost-effectiveness of building electrification, I've had more time to wrestle with the problem of what happens during extreme cold events. This work leads me to believe that the right near-term solution is NOT full electrification, as is being pursued in many jurisdictions, but instead partial electrification. I have a related pending IEPEC paper on this topic coming in

the fall, but I wanted to provide a little thought experiment to help people understand why we should be pursuing partial electrification instead.

IF we electrify everything, we will have new large winter capacity peaks for our grids to deal with, which will be rather expensive to build, given our current technology. **In one recent study, we found that the additional cost of meeting the winter peak capacity needs will add $17,000 in new grid capacity costs per home having its heating fully electrified.[1]** But that number is based on current costs of capacity. All of our zero-carbon means of providing cost-effective capacity right now provide capacity over short duration events lasting 2-6 hours, which aligns well with our current cooling-driven grid peaks. During an extreme peak winter day, the heating electricity load is remarkably flat relative to the current peak days, so that you're still left with a long duration winter peak constraint, lasting 12 hours or more. The current solution for this kind of capacity need is to run fossil-fueled (mostly with natural gas) backup generation.

Here's my thought experiment for my environmentally-focused friends:

Consider **what a heavily-electrified, low carbon 2050 energy system might look like**:[2]

1. **Large winter peaks that happen infrequently**, e.g. the 1 year in 10 or 1 year in 20 winter storm Uri event from February, 2021 have much higher winter capacity needs than the typical winter peak day.

2. **Electricity will be generated almost entirely using zero-carbon sources** (mostly solar and wind).

3. **The economics of meeting these extreme events will probably require the grid to still have a bunch of backup fossil-fueled generation that runs infrequently** (as in maybe only a day or two a year or every few years). So the grid has zero carbon emissions almost all of the time, but not actually 100% of the time.

4. **Zero-carbon sources are still providing 99% of energy needs**, but fossil-fueled sources are still important for capacity during long duration cold snaps.

Given a system that looks like that, let's consider your options as a "green" homeowner operating your heating system during one of these extreme peak events in a climate where the temperature gets down to 0 degrees:

Option 1: You get rid of your furnace and buy a heat pump with electric resistance backup. This has lowest upfront cost if your existing furnace needs replacing as well as your AC and you want to be 100% electric. During the extreme event, your 100% efficient electric resistance backup requires 10 kW of backup fossil-fueled generation running at 35% efficiency, giving you a net of **35% total system efficiency**.

Option 2: You get rid of your furnace and buy a cold climate heat pump that's also twice as big as the heat pump in situation 1. This costs you a lot of money, but now you can always run a heat pump instead of electric backup, provided the temperature doesn't drop below -15. During the extreme event, your 200% efficient cold climate heat pump requires 5 kW of backup fossil-fueled generation running at 35% efficiency, giving you a net of **70% total system efficiency**.

Option 3: You buy the same heat pump as option 1, but you keep your old furnace for backup instead of electric resistance. During the extreme event, your 80% (or 95%) efficient furnace requires 0 kW of backup fossil-fueled generation, giving you a net of **80% or higher total system efficiency**.

I have three conclusions based on this thought experiment:

1. **A heat pump with gas furnace backup quite possibly has lower overall emissions than a heat pump with electric resistance backup**, provided the heat pump is used A LOT. I'll have to do some more analysis to figure out where the breakeven point is in terms of the fraction of load that needs to be displaced, but my intuition says that you minimize carbon emissions by running a heat pump whenever there is significant zero carbon generation available or the temperatures are mild enough to get high heat pump efficiency. In a carbon-minimized future grid, we still expect to use fossil-fueled generation part of the time, even if it's only 1% of the time. During that time, heating with a gas furnace has lower emissions than even a cold climate heat pump.

2. **We need to come up with new long duration low-carbon emission capacity solutions if we want to 100% electrify everything.** That's still a really hard problem with no commercialized solutions. I have a few ideas, but there is no low-hanging long duration zero-carbon winter capacity fruit to be had.

3. In the meantime, if we're pursuing a minimum carbon emissions solution within some cost constraints, **we're better off pursuing partial electrification as a matter of policy**, keeping gas furnaces as backup and trying to minimize (but not eliminate) their use.

[1] This is calculated based on an incremental 10 kW load during winter peak, then taking the present value of the cost of providing this capacity with a capacity value of ~ 120/kW-year.

[2] You can think of this as kind of a more extreme version of the future modeled in this important NREL study: **Electrification Futures Study: Operational Analysis of U.S. Power Systems with Increased Electrification and Demand-Side Flexibility (nrel.gov)**