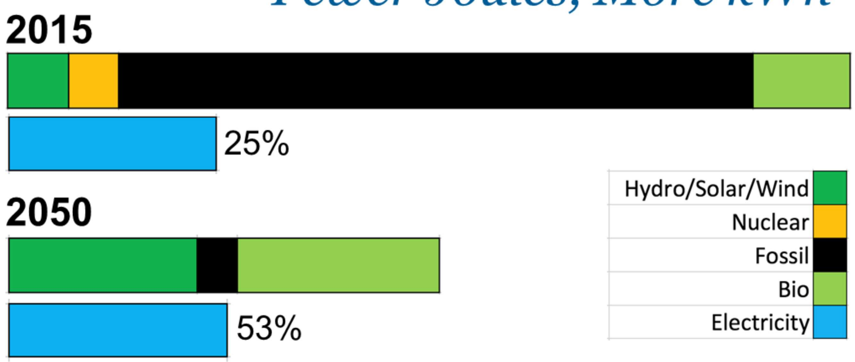
Opportunity Knocks for Beneficial Electrification

"Fewer Joules, More kWh"



Source: Vermont Comprehensive Energy Plan 2016

RAP® Energy solutions for a changing world

Opportunity Knocks …
for Beneficial Electrification

Presented by Jim Lazar
and Ken Colburn

May 16, 2017

The Regulatory Assistance Project (RAP)®

Questions

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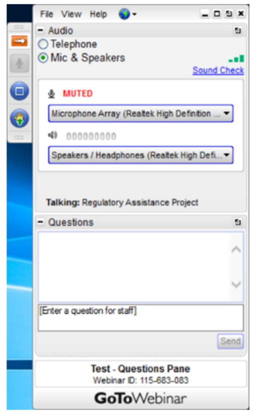

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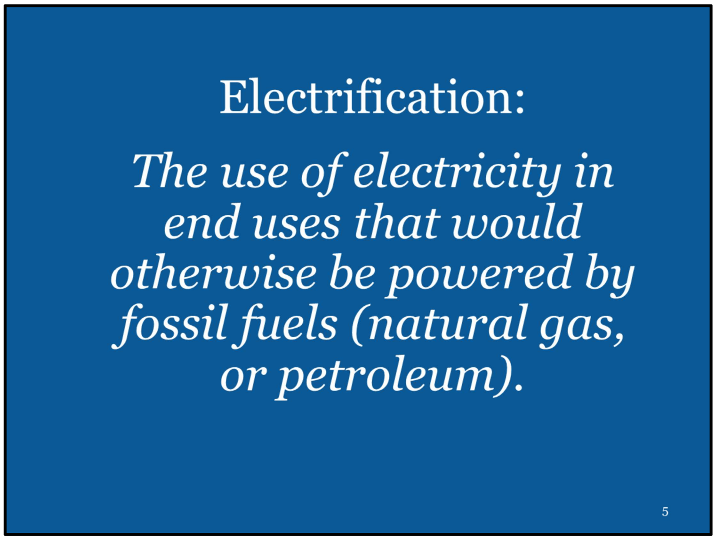
Our Experts

Ken Colburn

Jim Lazar



- Today’s webinar is about “Beneficial Electrification,” so let’s start with some background on what electrification is and why it’s important.

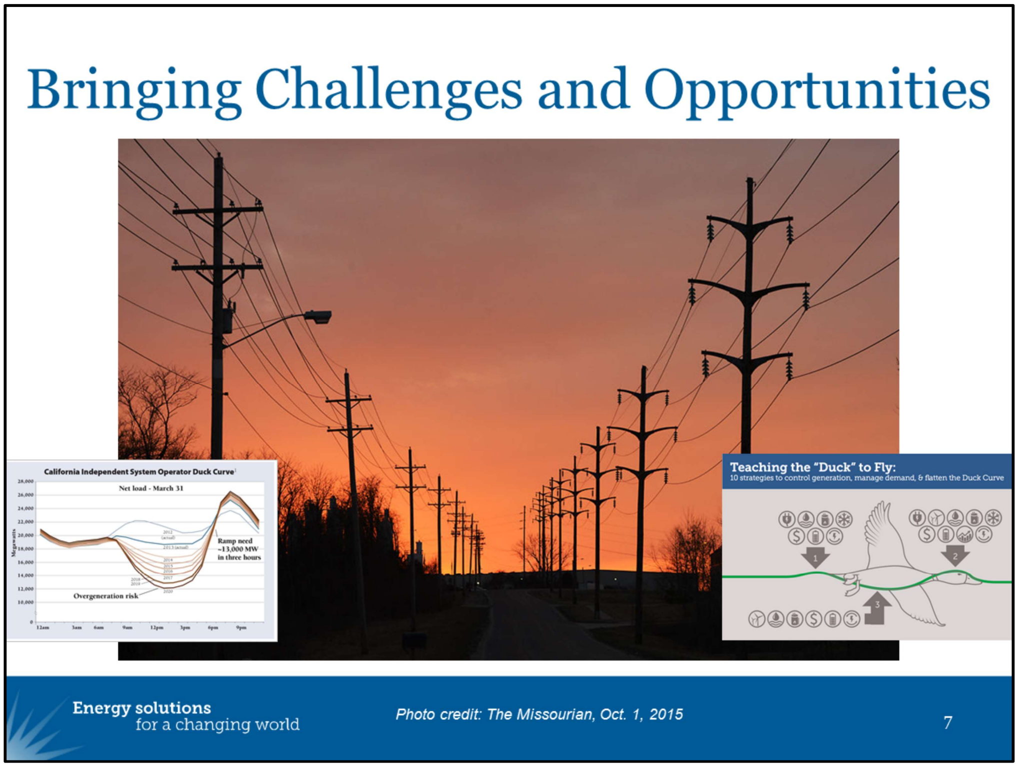
- Electrification just means – as indicated here – “***applying electricity to end-uses, like water or space heating or transportation, that would otherwise be powered by fossil fuels.***”

Why is electrification important? For a number of reasons, not least because it is happening already due to rapidly advancing technologies!

This is creating new business opportunities for utilities and others, both in load growth, new services, and customer engagement.

Bloomberg New Energy Finance, for instance, projects that electric vehicles may represent 35% of new car sales by 2040. Others suggest it will happen even sooner.

<Graph source: https://about.bnef.com/blog/electric-vehicles-to-be-35-of-global-new-car-sales-by-2040/ >



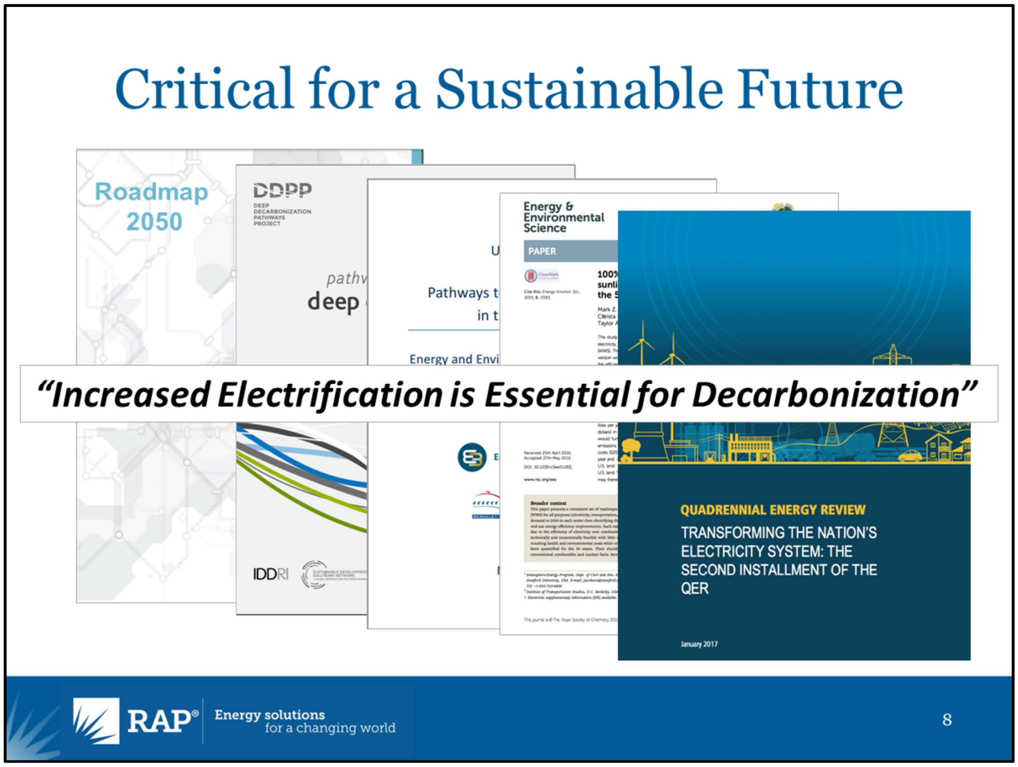
Second, we all recognize that, along with these opportunities, the electricity grid faces increasing challenges,

including the integration of distributed energy resources or DERs, as illustrated in the California ISO's famous "Duck Curve".

But as Jim Lazar's "*Teaching the Duck to Fly*" papers show, electrification can provide new ways to help meet these challenges.

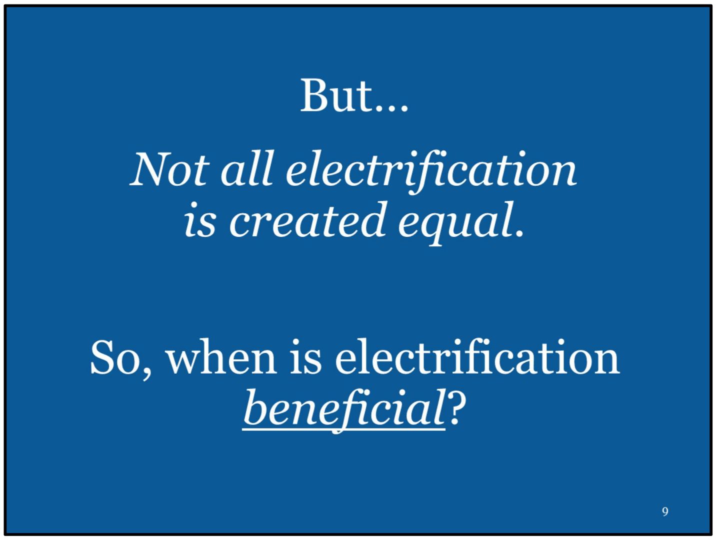
https://www.raponline.org/blog/teach-the-duck-to-fly-integrating-renewable-energy/

http://www.raponline.org/knowledge-center/teaching-the-duck-to-fly-second-edition/



Finally, the critical <u>environmental</u> importance of electrification is evident in the fact that virtually every major study or roadmap to address the threat of climate change has reached the same conclusion:

"Dramatically increased electrification is essential for deep decarbonization."



But, not all electrification is created equal… which begs the question:

When ***is*** electrification beneficial?

We consider a project or measure to represent **beneficial** electrification if it meets one of more of three criteria, **without adversely affecting** the other two:

1. Saves consumers money over the long run;

2. Reduces environmental impacts; and

3. Enables better grid management

Let's look briefly at each of these criteria.

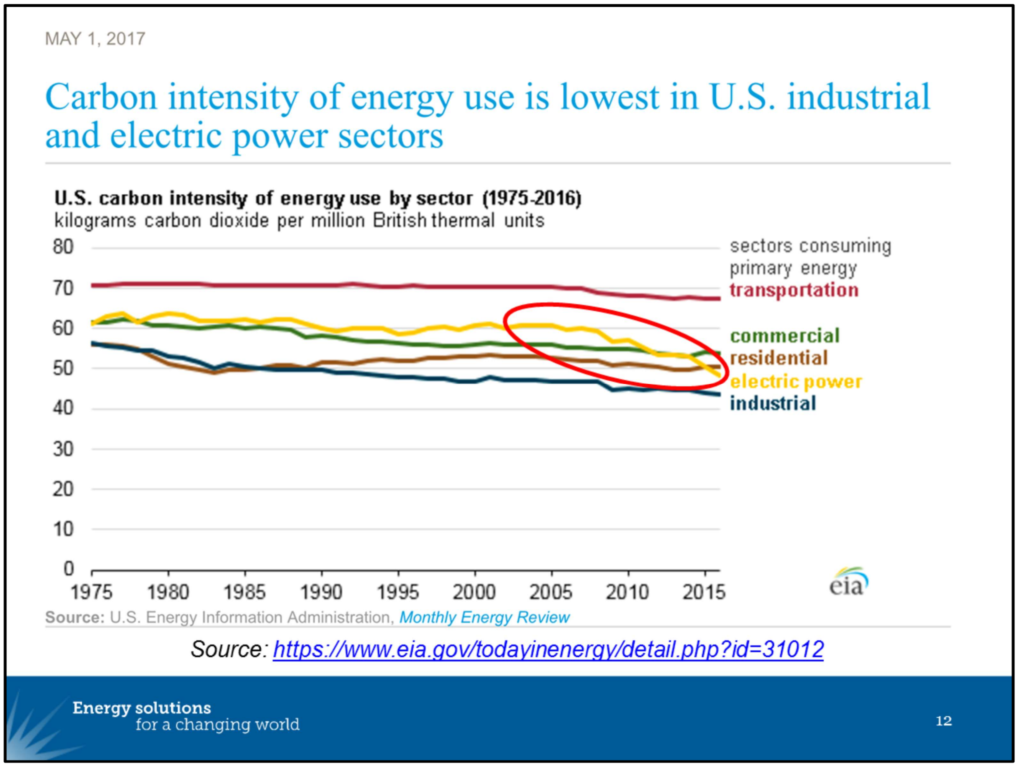
"Saving customers money" in the context of BE means that over its life, an action results in a <u>lower</u> total cost to provide that energy end-use (heating, mobility, etc.) to the consumer, and that's done by

- Looking over long run, not short-term;
- Including cost of acquiring and maintaining appliances, vehicles, etc.;
- Including any incentives provided; and
- Including utility bill savings from any time-of-use or ancillary services benefits of the measure.

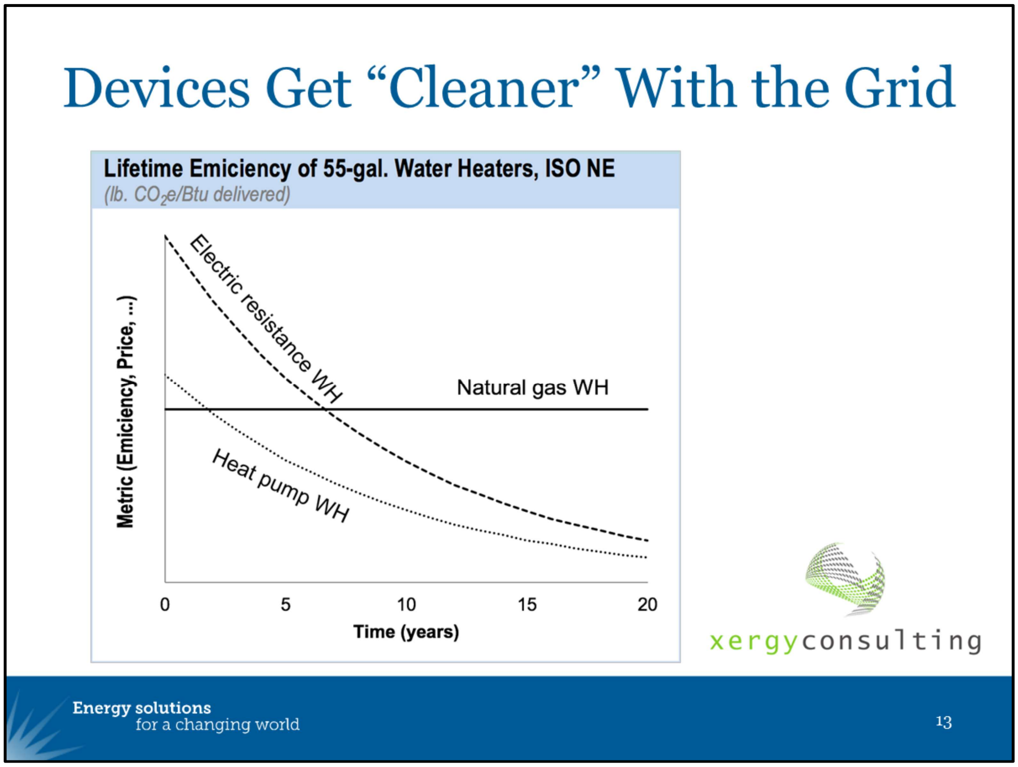
“Reducing environmental impacts” in the BE context means that the marginal emissions of the grid ***with*** the BE measure is **lower (cleaner)** than the emissions of the fossil fuels that are replaced to provide the consumer end-use:

- Again, over the life of the appliance or vehicle;
- Based on accepted resource planning criteria; and
- Including the grid flexibility created.

Environmental impacts are typically measured as CO_2 emissions for clarity and convenience, but the same benefits also apply to criteria and toxic pollutant emissions, as well as water use.



Regarding environmental impacts, it's important to note that BE devices "get cleaner" over time as the grid gets cleaner. This EIA graph shows how the carbon intensity of the electric power sector has improved dramatically over the last decade.



And as a result – as illustrated in this graphic from **X**ergy – …

while a natural gas water heater's "emissions efficiency" (or "emiciency," as we call it) will remain level over time, assuming no performance degradation…

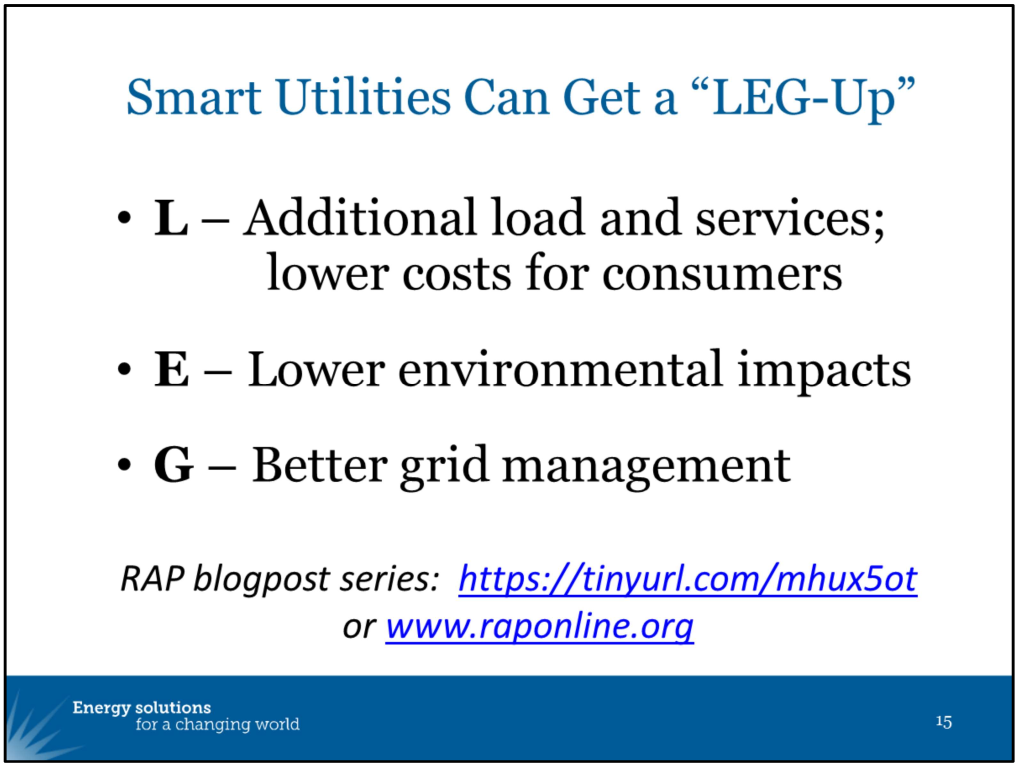
… an electric resistance water heater's emiciency will improve over time to become as clean, and then cleaner, than a gas water heater.

And a heat pump water heater has even better, quicker emiciency performance.

Third, *beneficial* electrification also offers the grid operator greater flexibility to better manage load, improve demand response, and integrate higher levels of renewable, non-dispatchable generation.

This can occur if:

- Some or all load can be controlled by the grid operator, such as through grid-integrated water heaters (GIWH), smart thermostats, or controlled water pumps;
- Consumers can program their loads to take advantage of time-varying rates; and/or
- The load shape, by its nature, fits the output of low-cost resources (like street lighting load, which largely occurs off-peak).



Some utilities – and regulators – may look at electrification simply as load growth, but we believe that smart utilities can get a "**LEG Up**" by approaching beneficial electrification consistent with the three criteria I just described.

RAP coined the "LEG Up" acronym to reflect:

- **"L":** Additional load, and more service opportunities, and lower costs for consumers;
- **"E":** Lower environmental impacts; and
- **"G":** Better grid management

In fact, we did a 4-part blog-post series explaining this "LEG Up" opportunity, which you can access on RAP's website.

Questions

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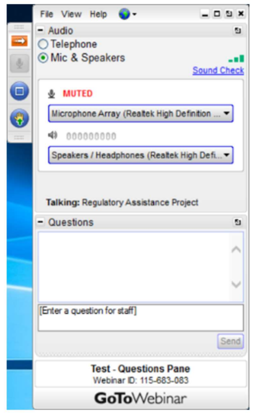
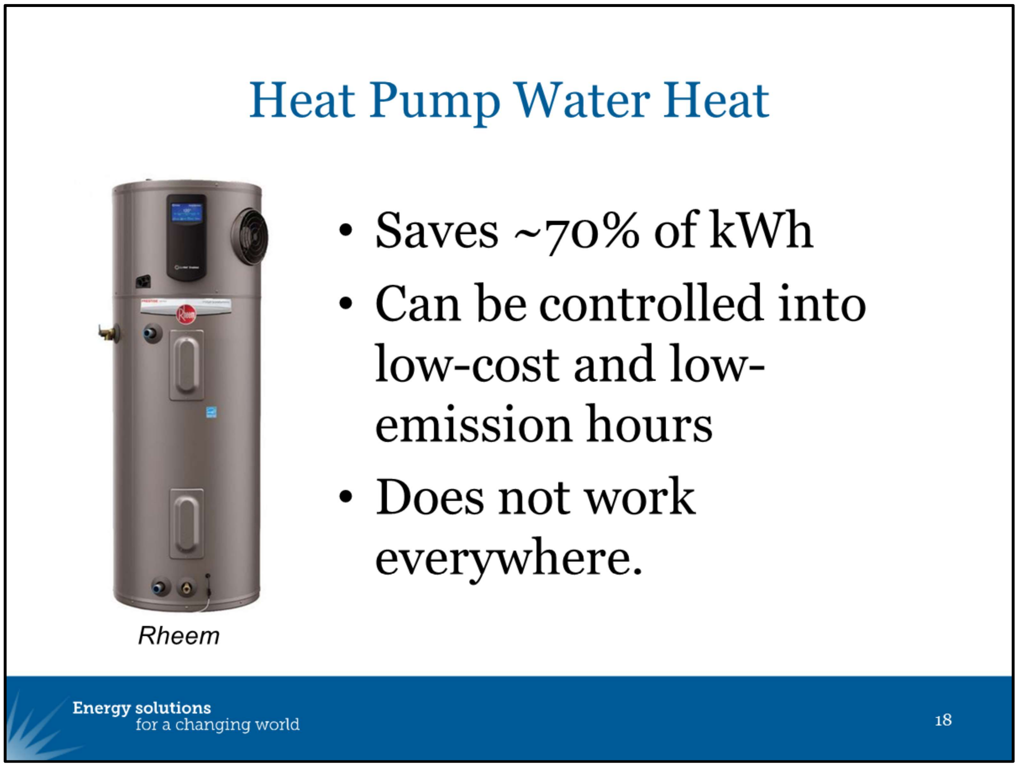


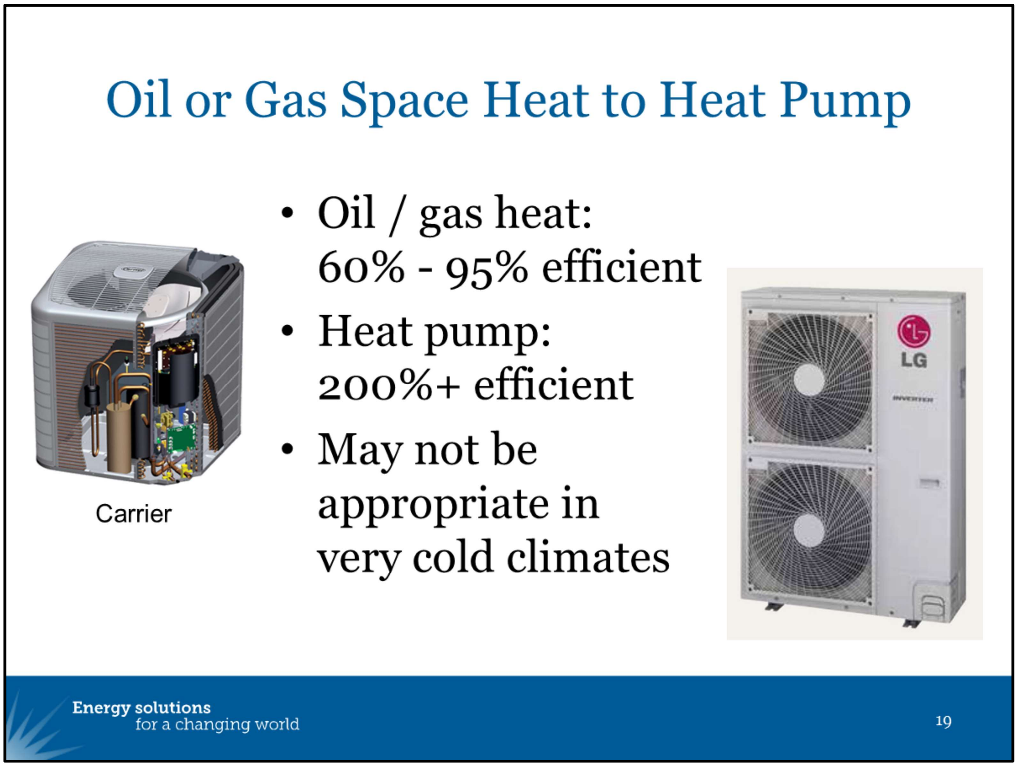
Examples



OK, now let's turn to some examples of beneficial electrification – and perhaps some that aren't so beneficial.

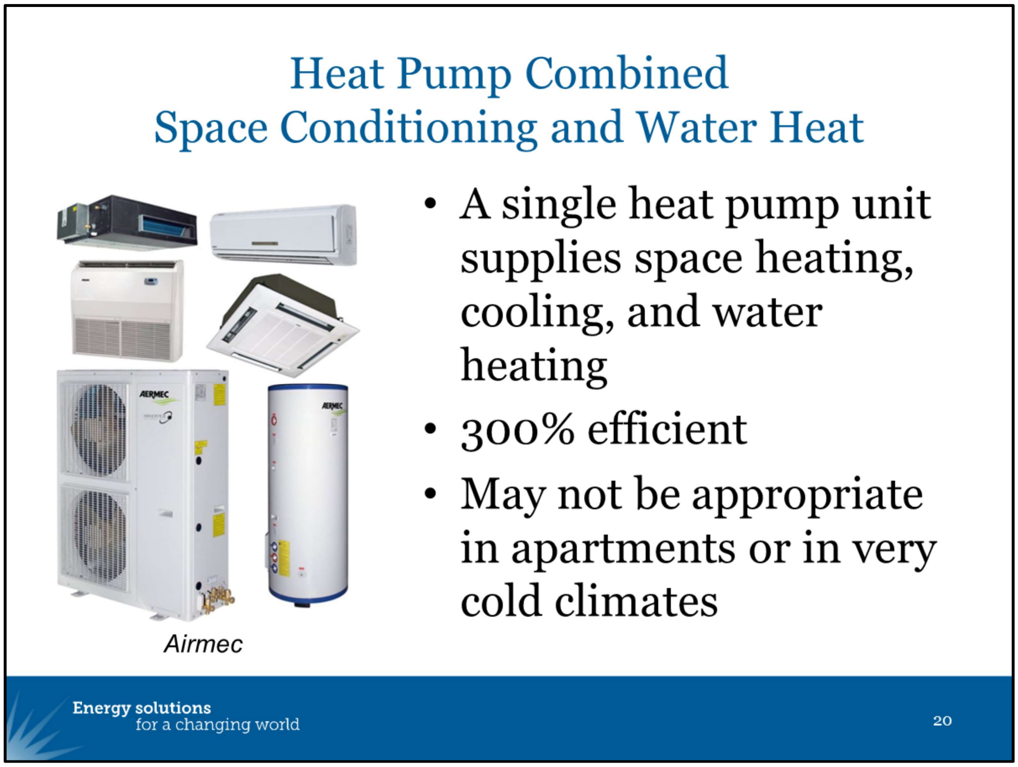
The first is converting from electric resistance to heat pump water heating. This saves 70% of the kilowatt-hours, and the water heater can be controlled into low-cost and low-emission hours.

But these units won't work everywhere.



A second example is converting oil or natural gas space heating to heat pumps.

Oil and gas heat are 60% to 95% efficient, while modern heat pumps are 200% to 300% efficient, depending on climate zone.



In fact, technologies are starting to be available that *combine* the functions of space heating, space cooling, and water heating!

These use heat pump efficiencies to really save a bunch of energy. In summer, they take heat out of the house and put it into the water heater.

Electric Vehicles

- Internal combustion systems: <25% well-to-wheels efficiency.
- Electric vehicles: ~75% (it matters where the incremental electricity comes from)

- Charging can be controlled into low-cost and low-emission hours

Another example that is certainly gaining traction recently due to a variety of cost, performance, and maintenance issues is electric vehicles.

The well-to-wheels efficiency of gasoline is poor. The battery-to-wheels efficiency of EVs is 3 times as great – but it matters a lot where the electricity comes from.

Because EVs only need to charge about 3 hours a day, they can be controlled into low-cost and low-emission hours.

Electric Resistance Water Heating in Low-Carbon Grids

- Water heaters only need to run 2-3 hours/day
- Can be controlled into low-cost, low-emission hours
- Important: Can also provide ancillary services to the grid

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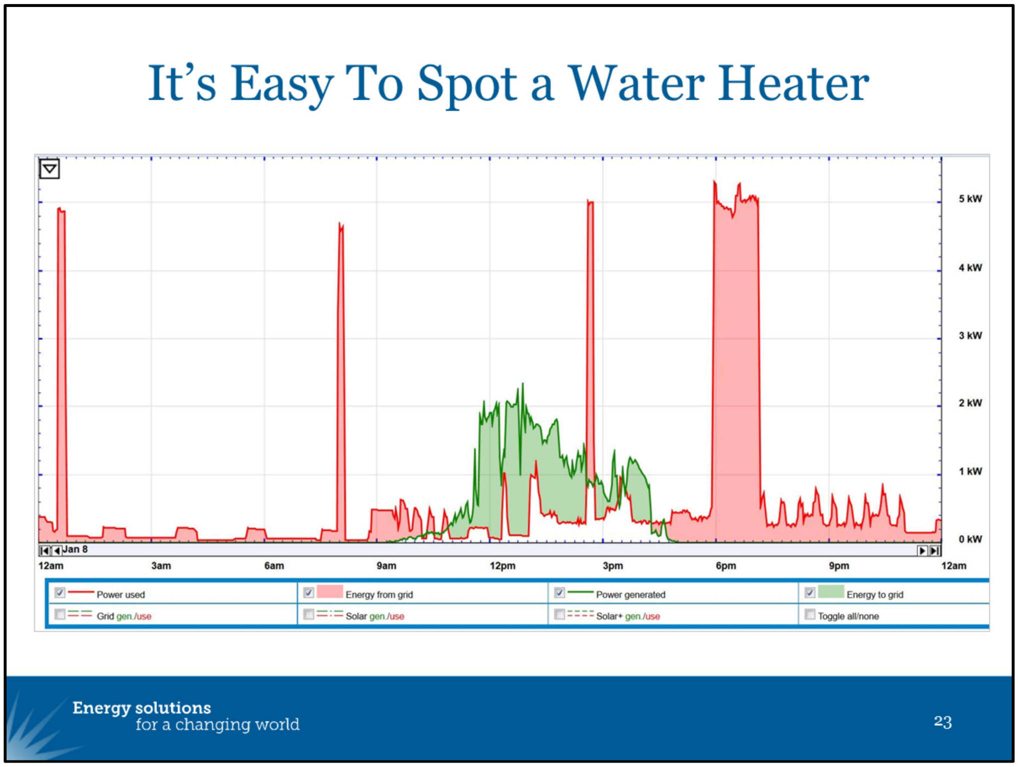
I'm going to take a little time to talk about water heating. Even an electric resistance water heater can be beneficial under the right circumstances.

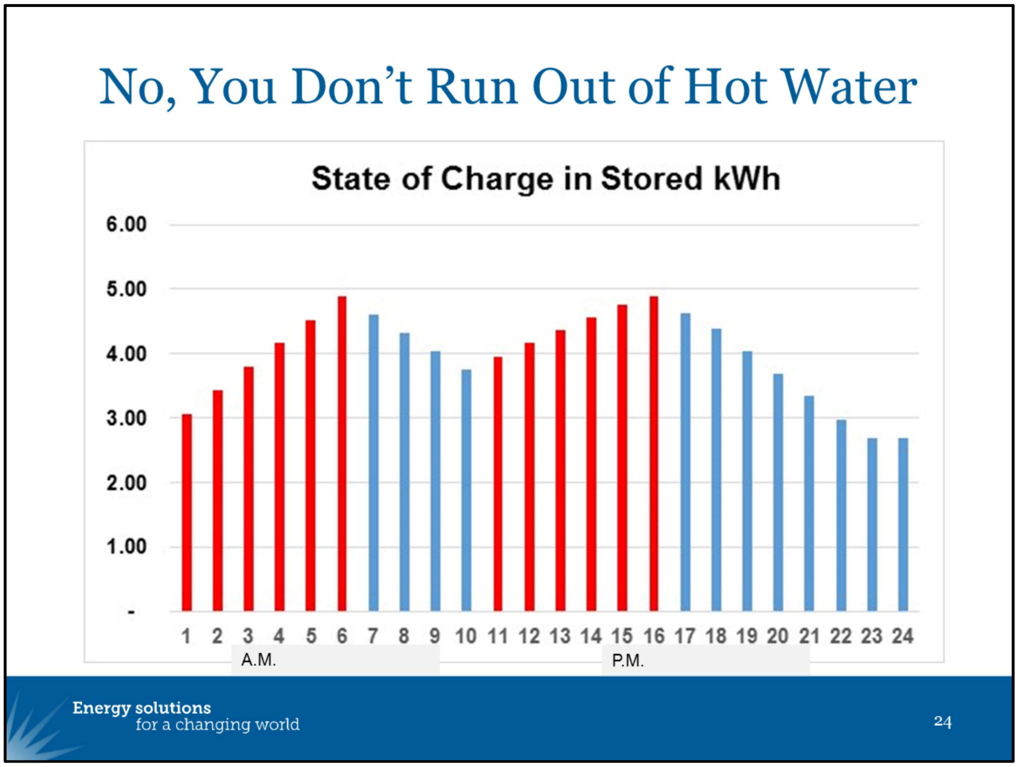
With modern controls, like those pictured, these can be managed to use power during low-cost and low-emission hours. They can also provide ancillary services to the grid.



It's easy to spot a water heater in the minute-to-minute data that modern smart meters can provide.

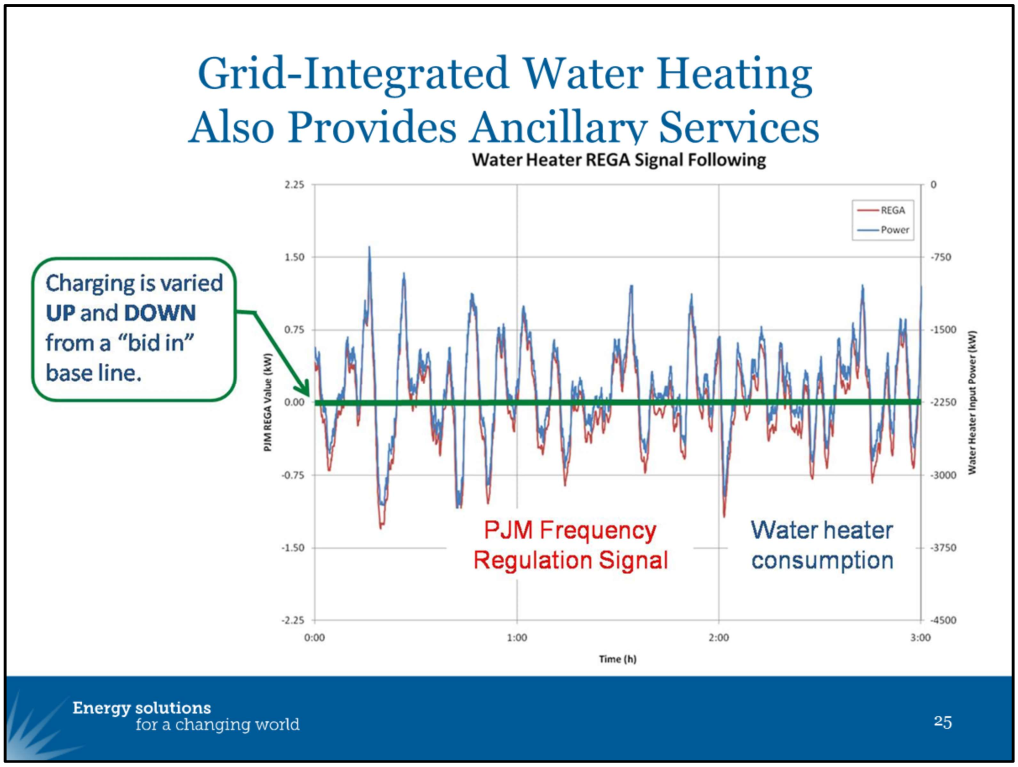
This is a 24-hour snapshot of a house in Seattle. The red is the electricity consumption; the green is the production of a solar PV system.

The 4.4 kW spikes shown here, occurring four times during the day, are the water heater coming on to make up for hot water used. It is very easy to compress this usage into the middle of the day (when the sun is shining) or the middle of the night (when the wind is blowing and power is cheap).



The first rule of controlled water heating is NO COLD SHOWERS. No, you don't run out of hot water. A 50 or 80 gallon tank is a lot of thermal energy storage.

This shows a controlled 50 gallon water heater in Hawaii. It charges up overnight, when wind power is plentiful. The customer draws it down when they wake up and use hot water in the morning. Then it charges up again during mid-day when the sun is shining. It seldom goes below half-full of hot water.

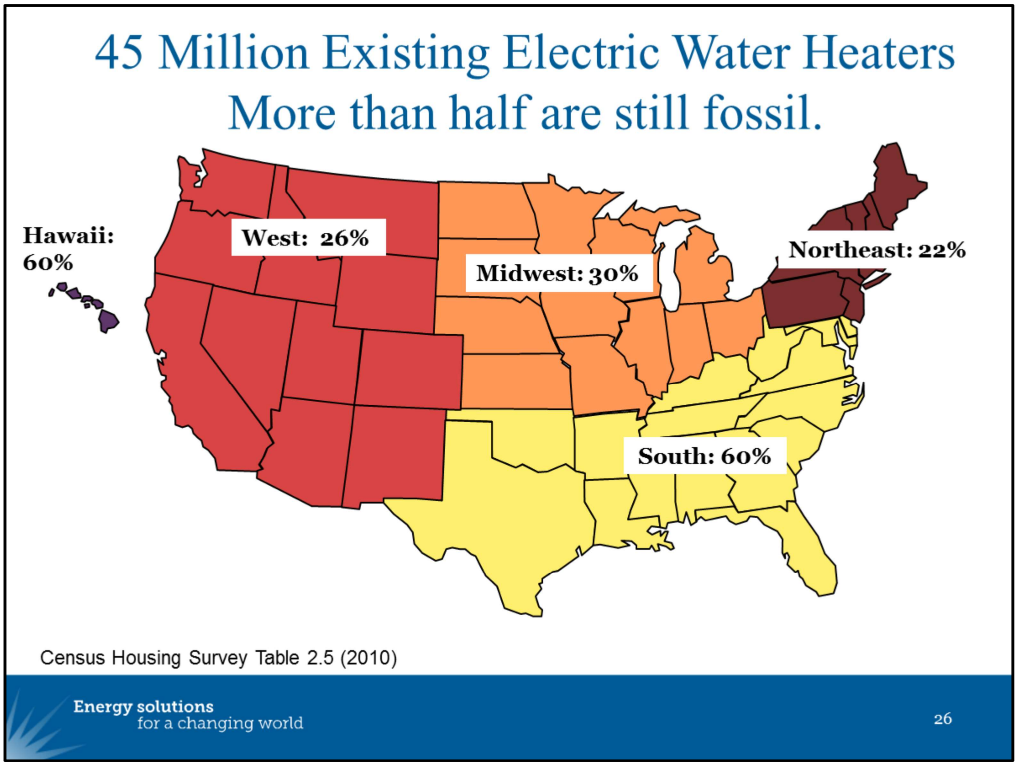


The ancillary services function is also valuable. Water heaters are simple resistance units, and you can turn them on and off second by second.

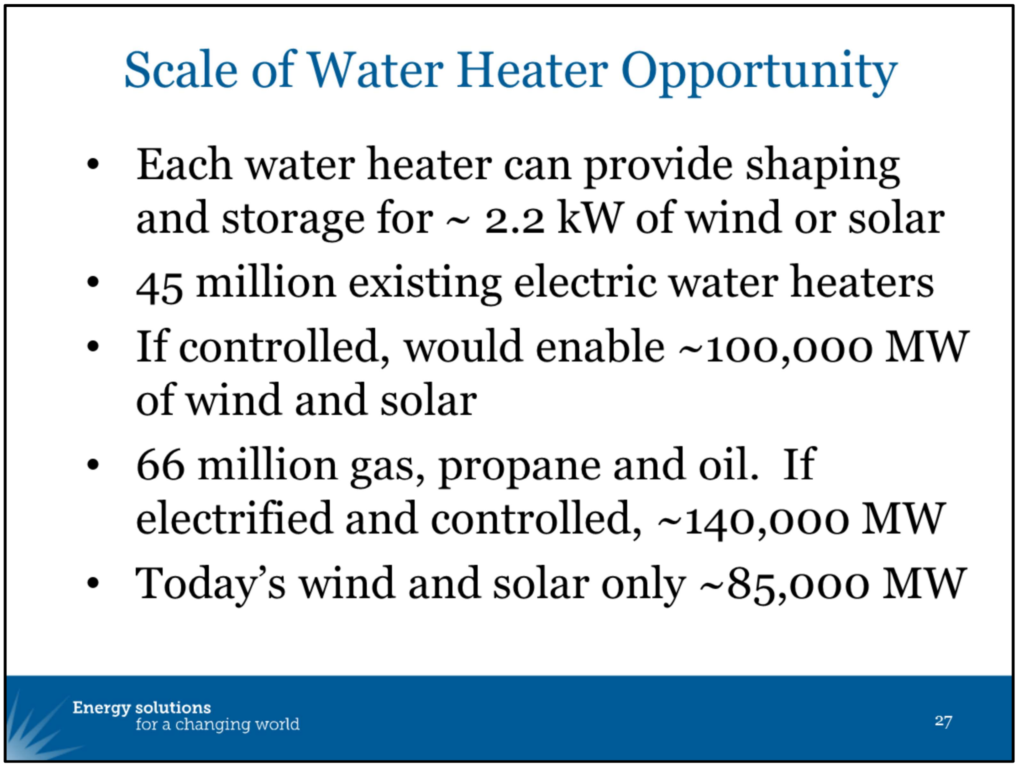
This graphic shows in red the PJM Frequency Regulation signal, and in blue the actual consumption of group of electric water heaters being controlled to follow this signal.

These water heaters can follow the signal much more closely than any generating unit can do. If you are a little over frequency, turn on some water heaters. If you are a little under frequency, turn some off. Since the tank holds a day's supply, the customer never notices.

Batteries can do the same thing. They just cost more.



Electric water heaters may seem like a small thing, but their saturation is significant across the country. It’s around 60% in the south and in Hawaii, and more like 25% in the rest of the country.



This is a big potential resource.

As variable renewables reach higher penetration, it's important to find the use for all of the output. And only some of it occurs when there is a lot of demand on the grid.

Each water heater can absorb the output of 2.2 kW of wind or solar that occurs outside of peak hours.

Multiply that by 45 million electric water heaters, and just controlling these units could enable us to double our wind and solar on US grid.

Questions

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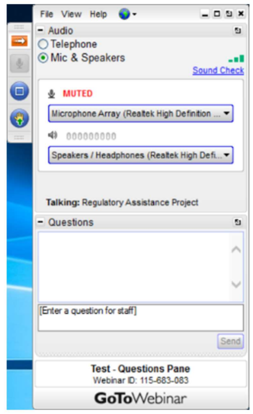

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Measuring BE

- Distinguish from EE, which is crucial but different
- EE goal: Use fewer kWh to do a task
- BE goal: Use fewer joules (by using more kWh)
- Emissions efficiency ("*Emiciency*") = total **CO2** emitted by the project vs. alternatives

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Beneficial electrification is different from energy efficiency.

Energy efficiency means using fewer kWh to do a task. That's a good thing.

Beneficial electrification often means using fewer joules – across all fuel types – but often means using more kilowatt-hours of electricity.

We've coined the term "Emiciency" to measure the emissions efficiency – how much CO2 is emitted by the project, versus alternatives.

Example **CO2** Calculation: Oil Space Heat to Heat Pump

Heating Oil

600 gallons/year = 80 mmBtu/year
@ 75% efficiency = 60 mmBtu heating
@ 161 #CO2/mmBtu = **6.4 tons CO2**

Heat Pump

60 mmBtu heating/3,413 Btu/kWh
@ COP of 3.0 = 6,000 kWh
100% coal = **6.0 tons CO2**
100% gas = **2.4 tons CO2**

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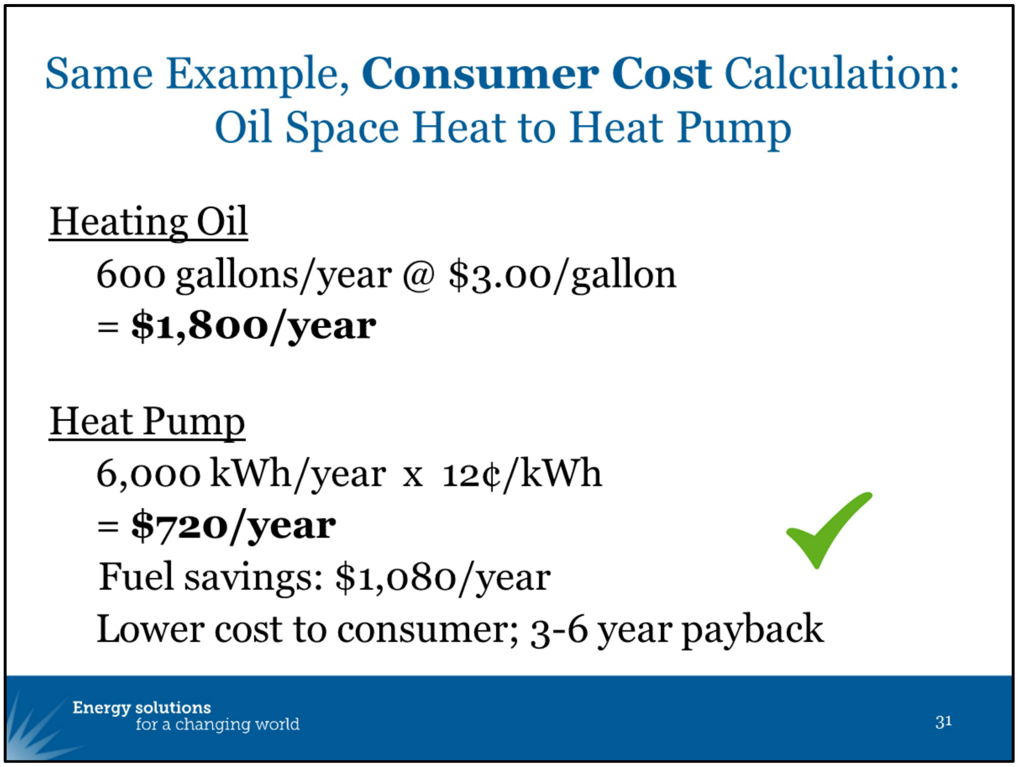
Let’s try some real numbers for converting oil space heat to electric heat pump space heat. I’ll start with the emissions, then do the money.

If a heating oil customer uses 600 gallons of oil per winter, they emit about 6.4 tons of CO2 from their furnace.

If we switch this to a high-efficiency heat pump, the same amount of heating will require 6,000 kWh/year.

If it comes from 100% coal, that’s about 6 tons of CO2. If it’s 100% natural gas-fired electricity, about 2.4 tons. So this checks out…the emissions are lower.

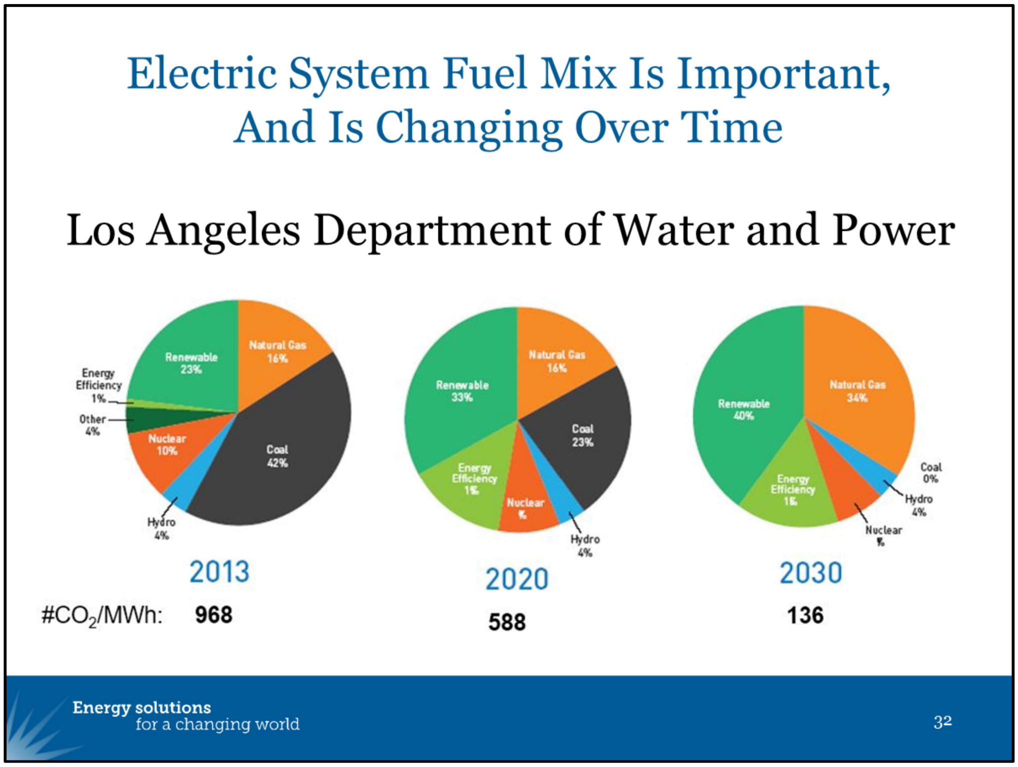


Next, the money.

600 gallons of heating oil at $3/gallon is $1,800/year.

6000 kWh of electricity, at the national average of $.12/kWh, is only $720/year.

The fuel savings of over $1,000 per year will pay for a heat pump retrofit in 3-6 years. So this also checks out as a good economic deal for the consumers.



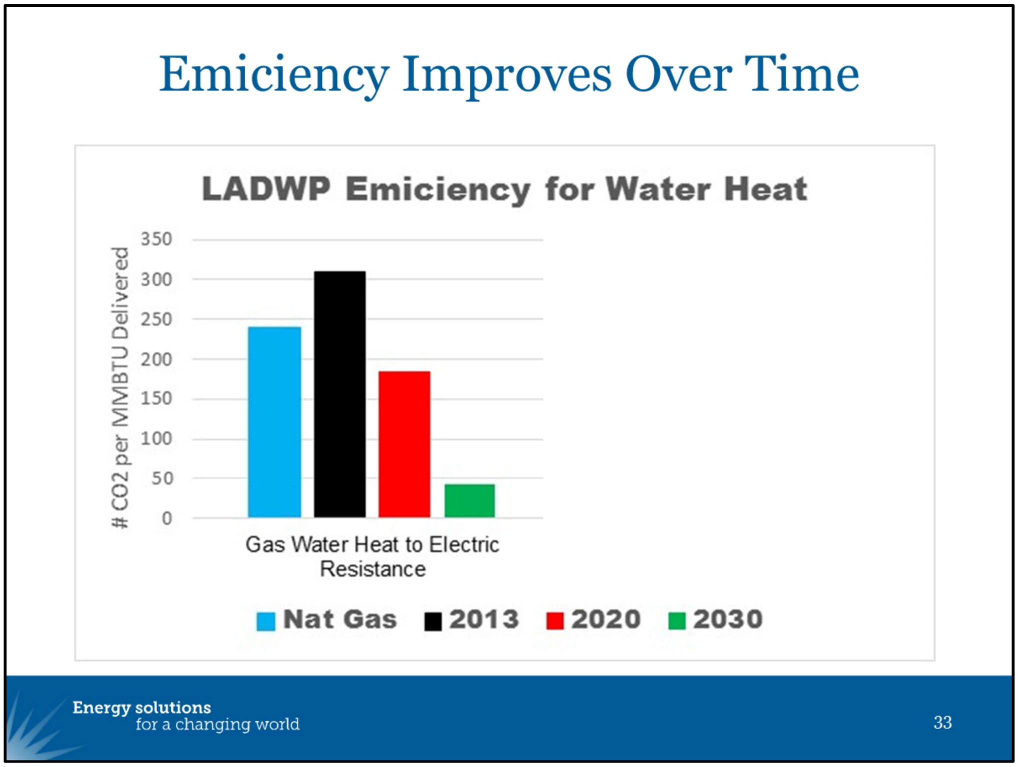
Electric system fuel mixes and carbon emissions change over time. I'll use the Los Angeles Department of Water and Power as an example.

In 2013, this utility was about 42% coal, and had emissions of 968 pounds of CO2 per megawatt-hour of electricity.

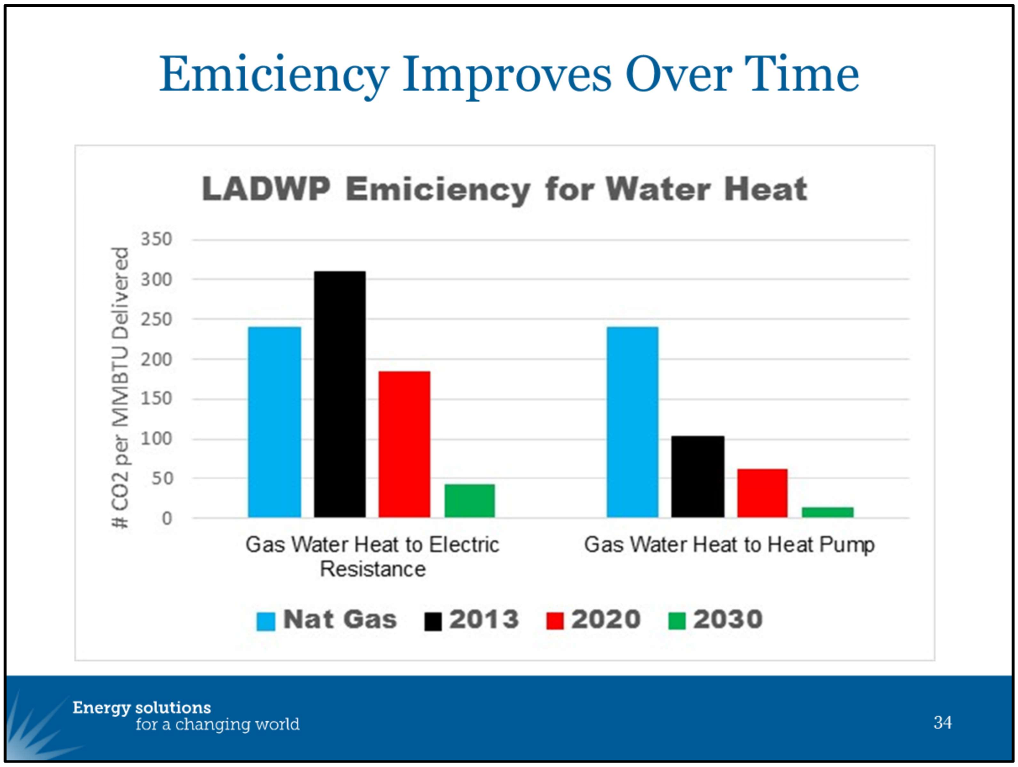
In 2020, the coal will be cut in half, renewables will surge, and the emissions will be down to 588 pounds/MWh.

And in 2030, all of the coal will be retired, and emissions will be down to 136 pounds/MWh, an 86% reduction.

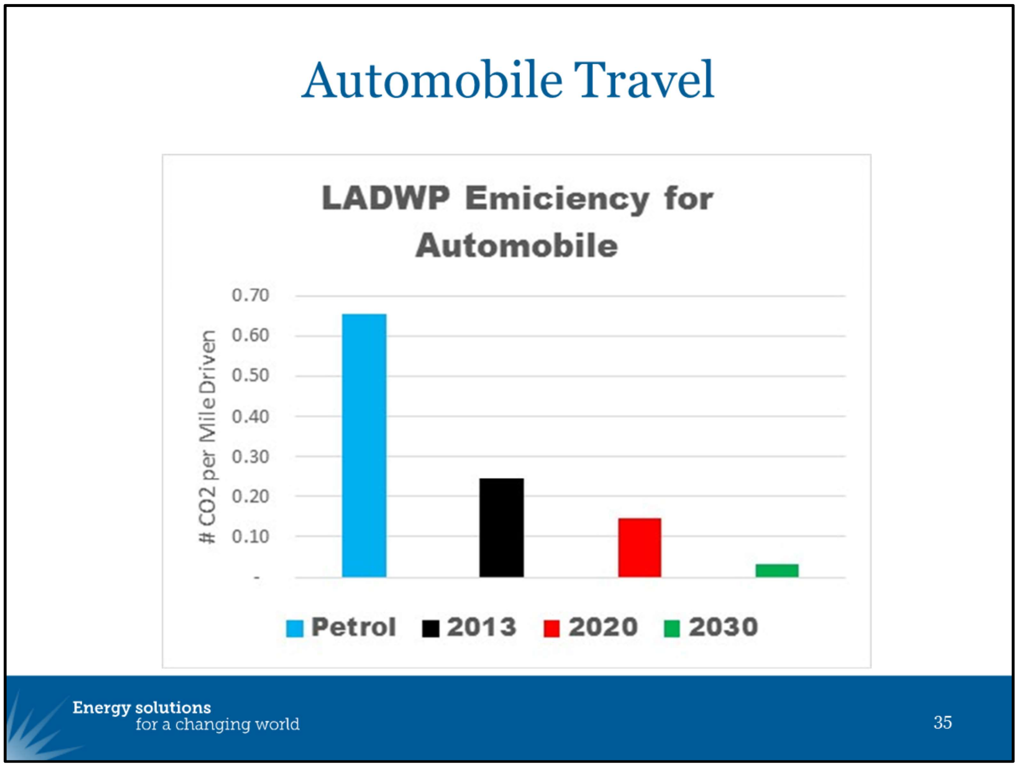
Therefore something that is NOT a beneficial electrification TODAY will likely become beneficial over the next 13 years.



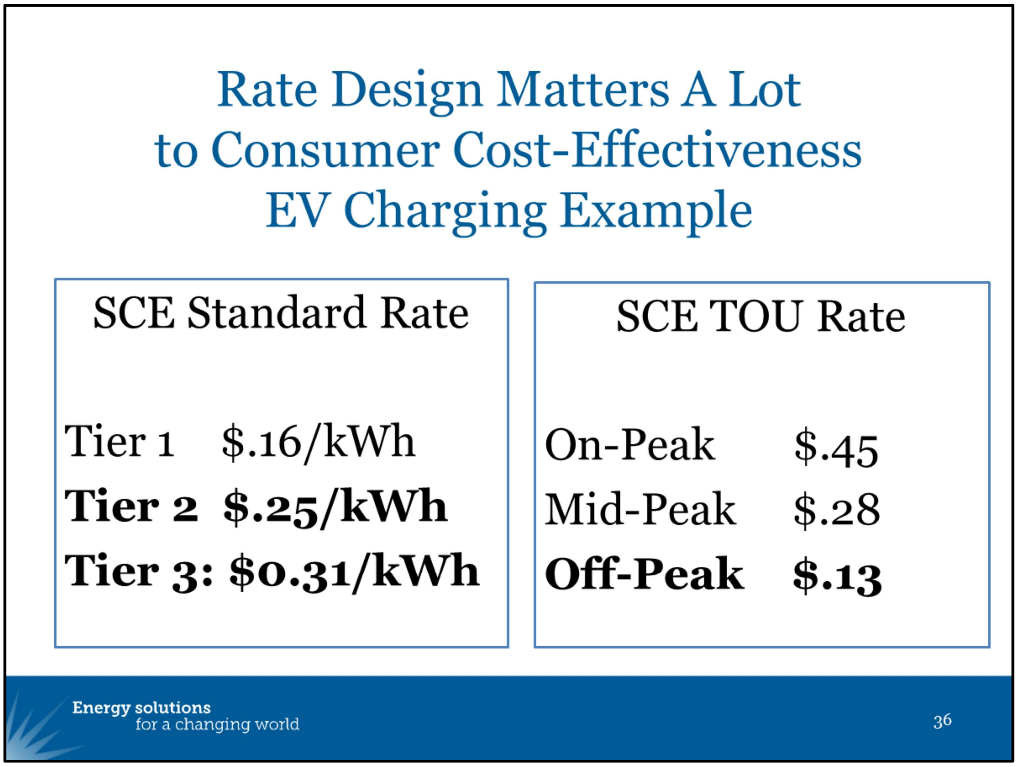
So, first, let's look at converting gas water heaters to electric resistance water heaters. With the 2013 fuel mix, this would increase carbon emissions. But with the 2020 and 2030 fuel mixes, there would be significant benefits.



But, if instead we look at conversions to heat pump water heaters, which work GREAT in the mild Los Angeles climate, the conversion is “emicient” even with the coal-heavy 2013 fuel mix. And, by 2030, the green bar shows we’ve reduced emissions associated with hot water by about 80%.



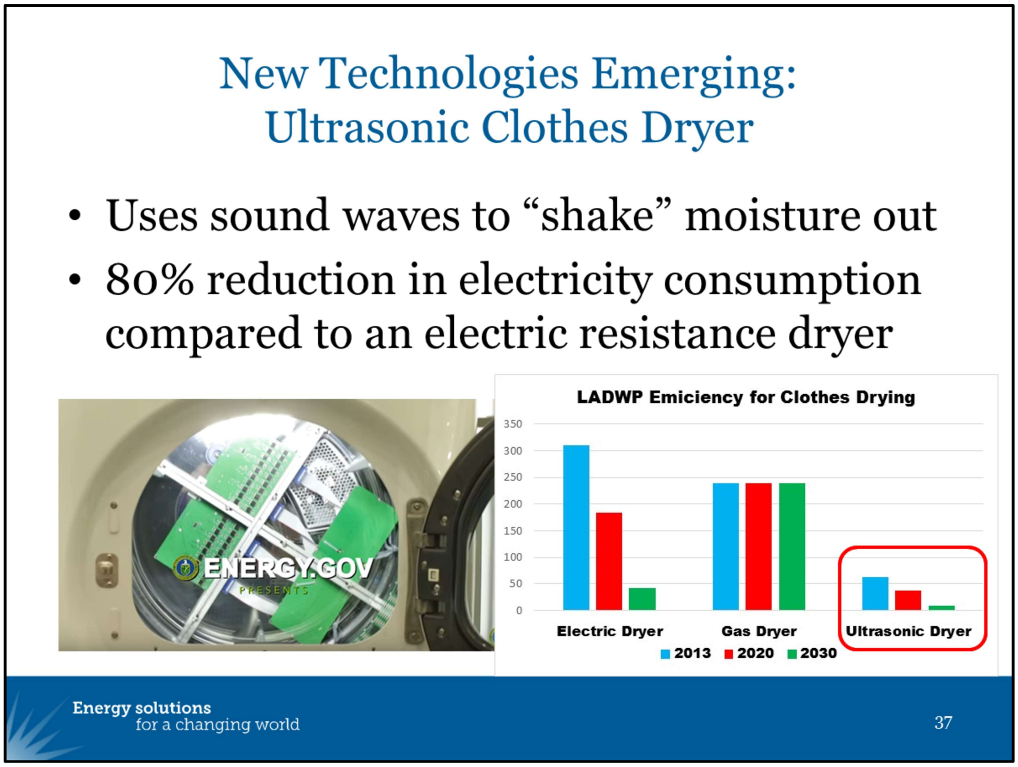
Automobile travel is a beneficial conversion even with the 2013 fuel mix. But, again, by 2030, the benefits are even greater.



Rate design matters a lot.

Southern California Edison is a high-cost utility. It's standard rate is a three-block inclining structure. Since nearly every customer uses their Tier 1 power to meet basic needs like lighting and the fridge, electric vehicle usage will be in Tier 2 or Tier 3, at $.25 to $.31/kWh. Hardly any savings over gasoline.

BUT, with the SCE optional Time of Use rate, the EV can do most of its charging overnight, at the off-peak rate of $.13/kWh, about half the equivalent cost of gasoline. RAP has several other webinars on rate design available on our website.



And there are new technologies emerging. One promising new option is the ultrasonic clothes dryer, that shakes the water off the clothing fibers with sound.

Electricity usage is dramatically reduced compared with conventional electric dryers.

Here I’ve pasted in the LADWP fuel mix over time. The first group of bars shows the emissions from a conventional electric clothes dryer. The second are the emissions from a gas clothes dryer. By 2020, even the electric resistance clothes dryer has lower CO2 than the gas dryer.

BUT, the ultrasonic dryer is a lower-emission product with any fuel mix. Available soon at an appliance dealer near you.

Slide 37

KC11 Should this slide go up with the other examples in the "Examples" section, rather than here in the "How to Measure" section, or is it a good capstone as we come to the end?
Ken Colburn, 5/11/2017

Emiciency Depends on Fuel Mix of the Electric Utility

		Marginal Resource on System to Serve Load				
	Existing Fuel $\#CO_2$/ MMBTU	100% Coal	50% Coal 50% CCCT Gas	100% CCCT Gas	50% CCCT Gas / 50% Non-Carbon	100% Non-Carbon
Utility System $\#CO_2$/MWh		2,000	1,200	800	400	0
Space Heating - Oil to Heat Pump	202					
Warm Climate 3,000 - 6,000 HDD		209	143	78	39	0
Cold Climate >7,000 HDD		314	215	117	58	0
Space Heating - Natural Gas to Heat Pump	130					
Warm Climate		209	143	78	39	0
Cold Climate		314	215	117	58	0
Water Heating - Gas to Electric Resistance	167	628	430	233	117	0
Water Heating - Gas to Heat Pump	167					
Warm Climate		209	143	78	39	0
Cold Climate		314	215	117	58	0
Clothes Drying - Gas to Ultrasonic	167	157	108	58	29	0
	$\#CO_2$/Mile					
Automobile	0.65	0.54	0.37	0.20	0.10	0

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I'll wrap up with a summary slide that shows how each of these technologies compares to the fossil-fuel alternative. We've computed this for systems that are 100% coal, 50% coal and 50% gas, 100% gas, 50% gas and 50% non-carbon resources, and 100% non-carbon resource. You can roughly put your utility in one of these categories.

Where the matrix shows red, electrification will increase emissions. Where it is yellow, they are about the same. And green means a significant reduction in emissions.

Basically, once the power system gets to 100% gas or a mix of gas and non-carbon resources, every one of these options is beneficial from an emissions perspective.

The economics are more complex, and we won't try to generalize these. They are very location-specific, as every utility has different rates, and every region has a different climate.

Questions

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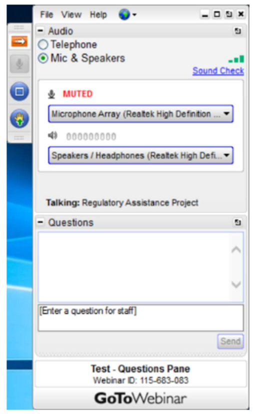

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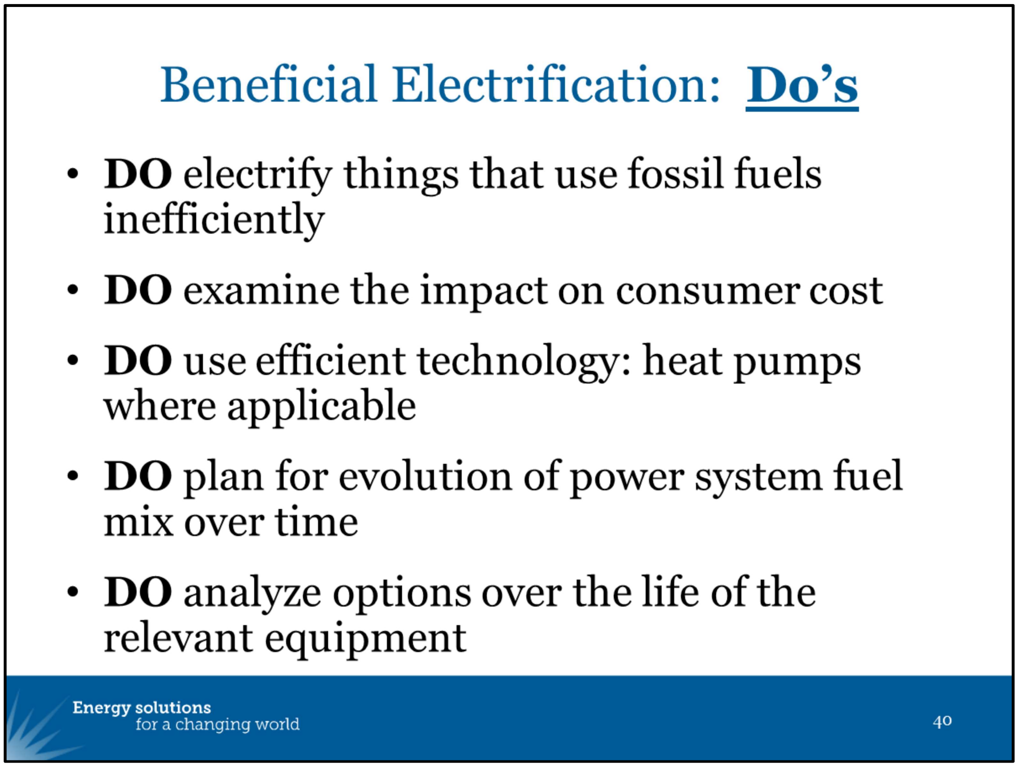
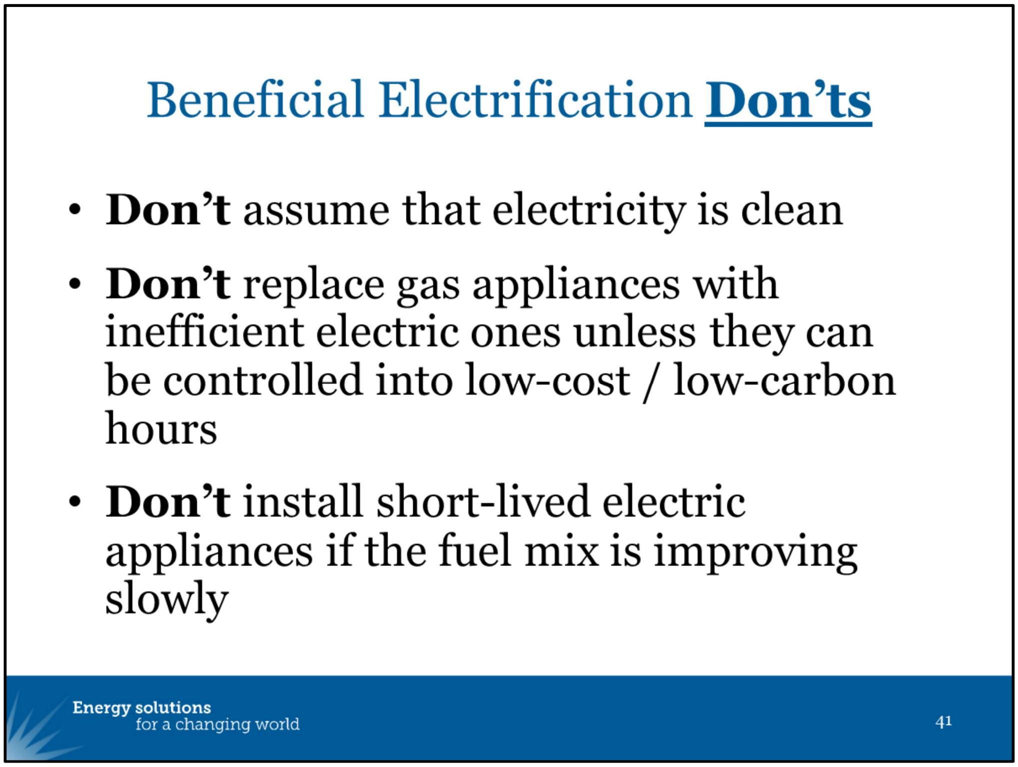


In the "Do's" category, be sure to:

1. Electrify devices that currently use fossil fuels inefficiently;
2. Look at the impact on consumer cost;
3. Employ the most efficient technologies possible, especially heat pumps, and especially in new construction;
4. Anticipate and plan for the evolution of the power system fuel mix over time; and
5. And in that context, analyze electrification options over their entire useful life.

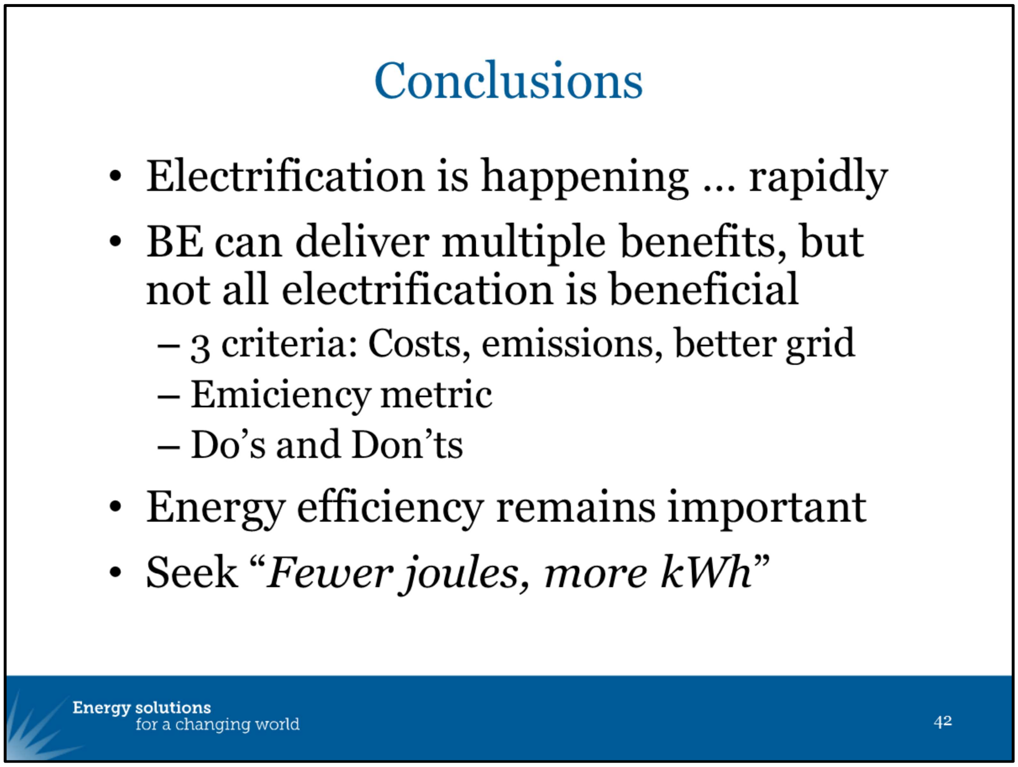


Over on the "Don'ts" side:

1. Don't simply assume that electricity is cleaner (it depends on the system fuel mix serving your area and how long that mix is likely to prevail);

2. Don't replace natural gas appliances with inefficient electric ones – unless they can be controlled to run or charge in low-cost, low-emission hours; and

3. Don't install short-lived electric appliances if the system fuel mix is improving only slowly.



Let me wrap up by indicating that electrification is <u>happening rapidly</u> due to advances in technology, but there are <u>better and worse ways</u> to do it.

Done correctly, <u>***beneficial***</u> electrification can deliver multiple societal benefits <u>***if***</u>:

- It adheres to the three criteria we cited (lower total cost, lower environmental impact, and better grid management);
- Applies the "emiciency" metric; and
- Follows prudent Do's and Don'ts

Finally, remember that BE does <u>not</u> take the place of EE!

A good way to conceptualize the two is working hand-in-hand: when you undertake EE efforts, you can use the resulting "<u>energy bonus</u>" of saved kWh to electrify another end-use!

The ultimate point is to utilize less raw energy – joules -- to accomplish end-uses. And this is trending toward being most effectively accomplished when more of those joules are in the form of electricity.

Back in November, we did an introductory BE webinar with Keith Dennis of NRECA, who has done pioneering work on the subject. In this webinar endeavored to introduce criteria for BE, indicate how emiciency could be measured, and provide some examples. We recognize that the Conclusions, and the “Do’s and Don’ts” of today’s webinar are still pretty general in nature. RAP will be working over the next several months to develop and clarify these issues and to develop specific policy recommendations. In the meantime, we can also address these issues in our Q&A session.

Thank you all for joining us today.

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About RAP

The Regulatory Assistance Project (RAP) is a global, non-profit team of experts that focuses on the long-term economic and environmental sustainability of the power sector. RAP has deep expertise in regulatory and market policies that:

- Promote economic efficiency
- Protect the environment
- Ensure system reliability
- Allocate system benefits fairly among all consumers

Learn more about RAP at www.raponline.org

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