OTHER SPS TECH

Electrical Components

Circuit

A closed loop that current flows in, with energy transferred to loads.

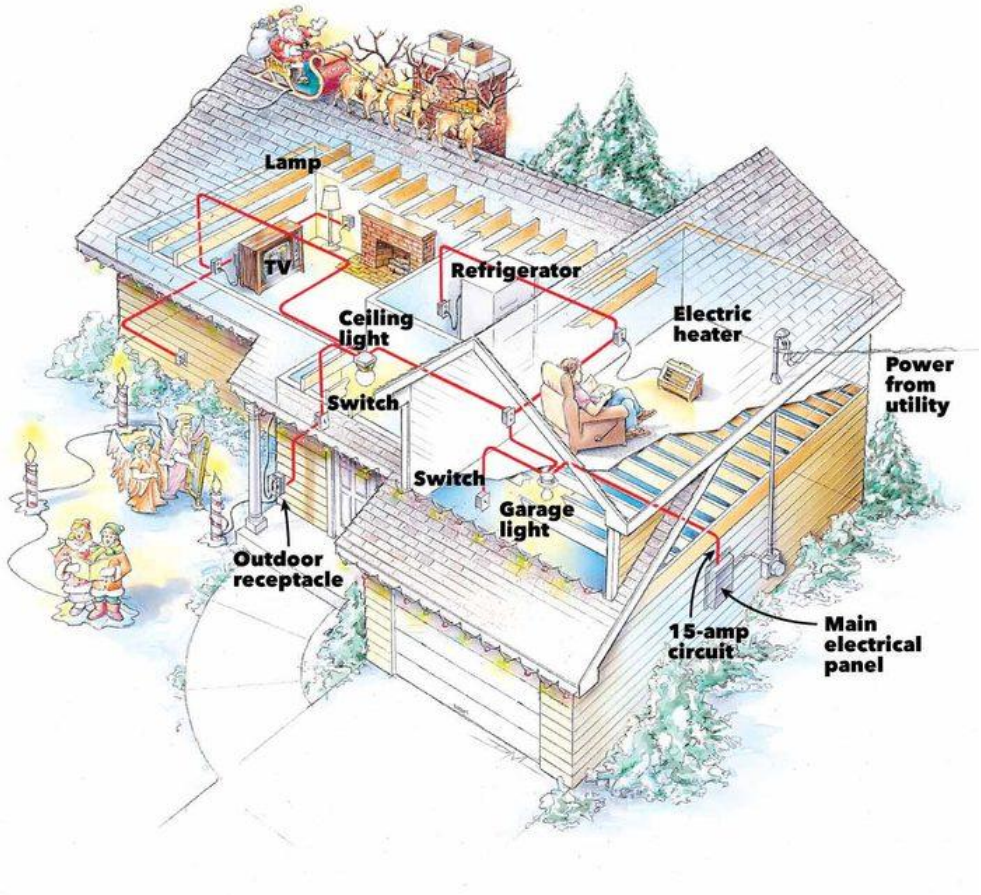


Image: Family Handyman

Circuit breaker (CB)

A safety device that detects current overloads.

...When this happens, it stops the current flow in that circuit.

120 volts

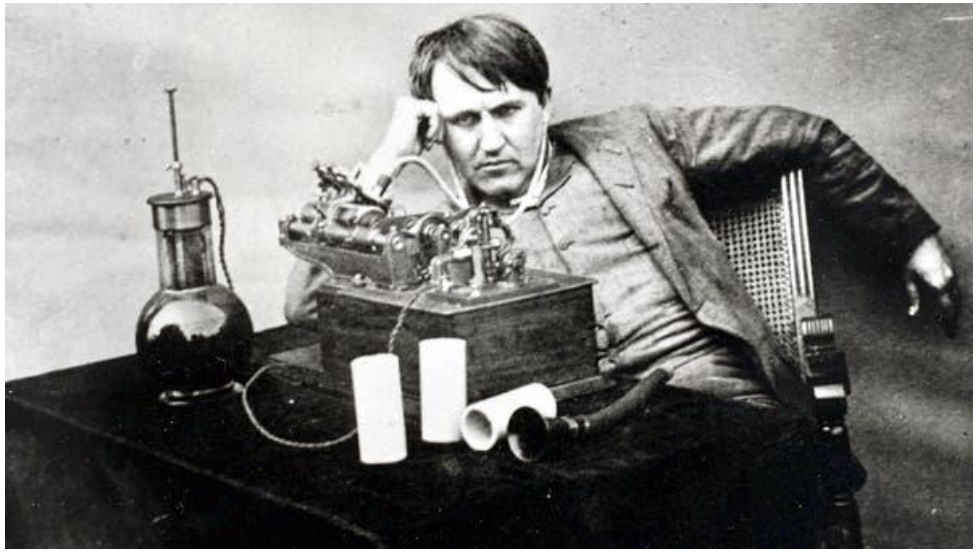
240 volts

Overcurrent device

Mechanical circuit breaker

A thermal and/or electromagnetic circuit breaker.

Invented by Thomas Edison in 1879.



Digital circuit breaker

Stop and start current using power semiconductors.

Respond “3,000 times” faster than mechanical breakers.

Monitor the circuit’s power.

For some options: Remotely adjust the maximum current.

Should include GFCI and AFCI protection.

Solid-state circuit breaker
Smart circuit breaker

“3,000” source: Atom Power

Electrical panel

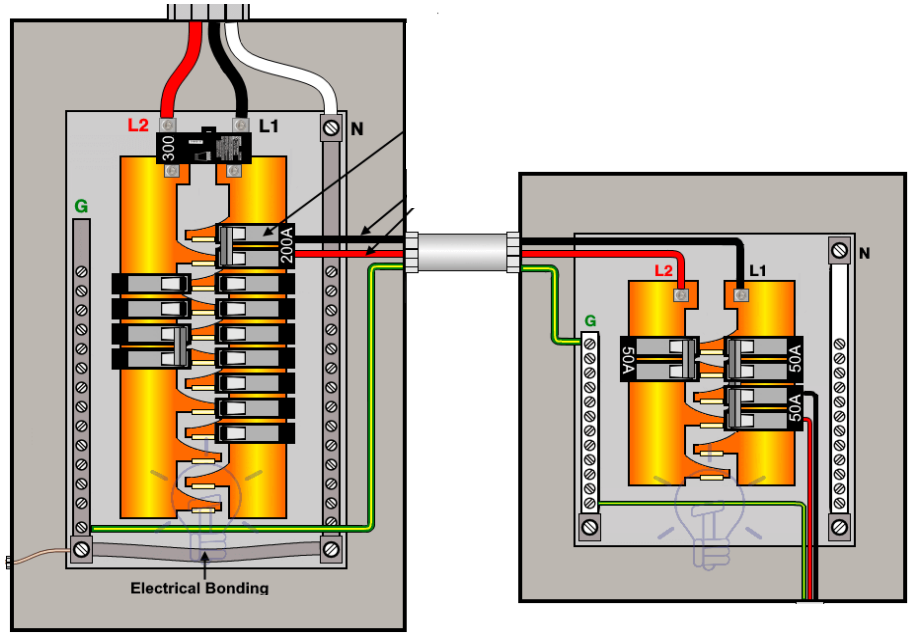
An enclosure where power is distributed from supply sources to load circuits.

Breaker box
Load panel
Load center
Service panel
Distribution panelboard

Subpanel

A downstream distribution panel, for a subset of loads (or all loads).

These loads could stay available during islanding.



Main panel

Subpanel

Critical-loads panel

Image: [Electrical Technology]

120% rule

Total source-breaker ratings can’t be more than 120% of the busbar rating.

100-amp busbar rating
100-amp main breaker

20-amp max PV breaker
Max PV system: ~5 kW

Electrification problem

To support the new electrical loads...

The 120%-rule constraint often requires upgrading the utility service.

For example: 200 amp service → 400 amp service

The related cost and delay could derail the project.

...Especially if a utility-equipment upgrade is required (at the customer's expense).

Hacker News

BrentOzar

I'm in the midst of trying to get an electric car charger installed in my garage.

I live in Las Vegas, in a 25-year-old subdivision. The homes' 200-amp panels don't have enough spare capacity to add a charger. (3 old less-efficient HVAC units, pool pumps, hot tub, electric oven, clothes dryer, etc.)

So to add a charger, I have to get my home's service raised to 400 amps. That wouldn't be a big deal, except... the neighborhood's transformers are already over capacity, too. A few of the homes already added 400-amp service so they could add Tesla chargers, and there's no capacity left in the neighborhood.

Nevada Energy is willing to add a new transformer in the neighborhood - but they want to charge me $20,000, plus the costs of trenching the new 400-amp line from the transformer to my house, plus the new panel, plus the charger. It's looking like a $40,000 installation.

Source: Hacker News, 2023

One 120%-rule workaround

Move ALL load breakers from the panel to a higher-rated subpanel.

Tie the PV system into the subpanel.

Add appropriate signage to the main panel...

One 120%-rule workaround

Existing main panel

New subpanel

One 120%-rule workaround

Existing main panel

New subpanel

Energy Management System (EMS)

A part of an electrical system that monitors and controls power.

Power control system (PCS)

An EMS subset that controls power sources and/or loads....

...To keep current within equipment / conductor ratings.

This is an NEC-accepted alternative to a utility-service upgrade.

UL 1741 CRD >> UL 3141

Power control systems in the NEC

Thank you Bill Brooks, John Bernder, and others. 💪

THE MAXIMUM CURRENT BACKFED BY THIS SYSTEM TO THE MAIN PANEL MAY BE CONTROLLED ELECTRONICALLY. REFER TO THE MANUFACTURER'S INSTRUCTIONS FOR MORE INFORMATION.

PCS CONTROLLED CURRENT SETTINGS: _____ AMPS

mcbishop

> So to add a charger, I have to get my home's service raised to 400 amps.

National Electrical Code 2020 says you can use a "power control system" (i.e. software) to ensure your busbar isn't overloaded (avoiding the service upgrade).

Related "smart panel" options to check out: Span, Lumen Smart Panel, Savant Power Systems

reply

> mywittyname
>
> I've heard of people using this with 100A service to great success. So it should work very well with 200A.
>
> That being said, code is code. So if the local codes won't allow the OP to use this, then they are still stuck.

Source: Hacker News, 2023

Smart electrical panel

A panel that incorporates digital technology.

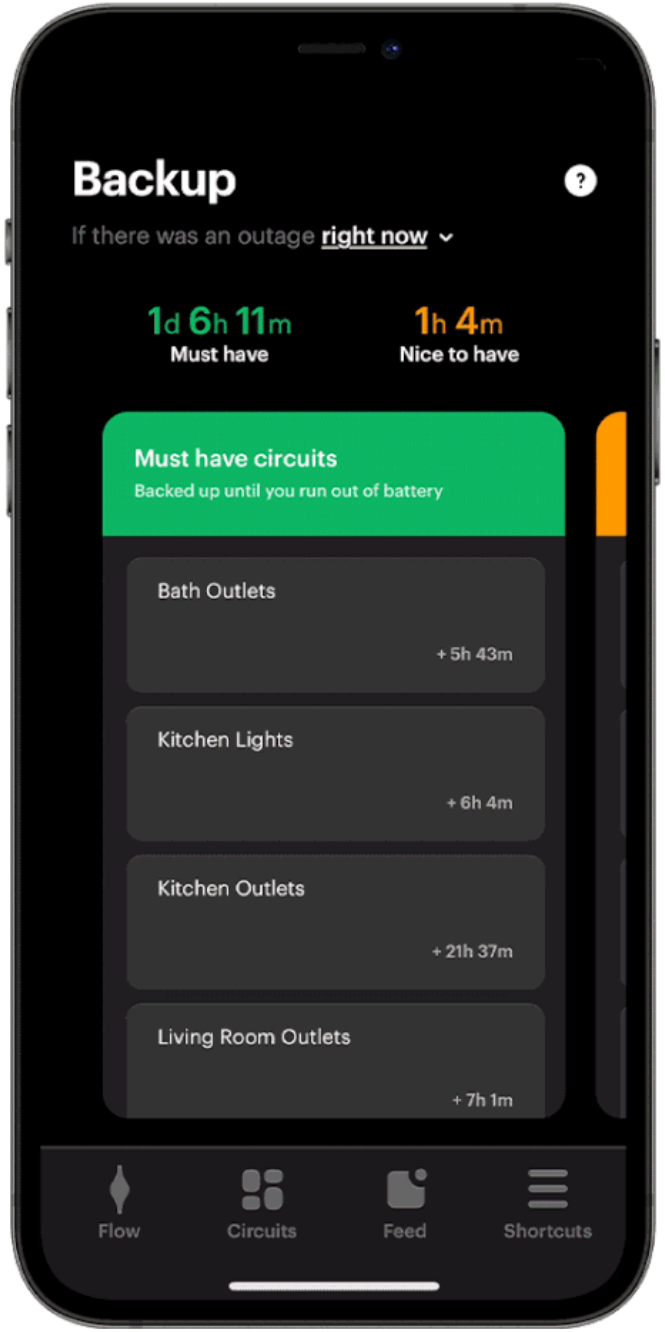
Span

Savant

ABB

Leviton

PCS logic



GIF: Span

Power-control systems help the grid

Electrification will strain some electric grids.

Widespread PCS use could reduce this strain.

...And reduce electric-grid upgrade costs.

Putting the grid on the periphery

A power control system treats the utility as just another power source. It’s a whole new way of looking at how we supply power.

— Bill Brooks

Solid article on Power Control Systems

Electrification

Electrification

Replace hydrocarbon loads with electric loads.

Gas furnace

Heat pump

Electrification

Replace hydrocarbon loads with electric loads.

Gas F150

Electric F150

Why offer electrification?

Larger PV system.

Larger battery (maybe).

Larger overall contract (and more profit).

Make your work more interesting and (maybe) more fulfilling.

Prospect interest in electrification?

If yes, will you show any electrification options?

…Or at least model them?

Natural-gas load	Could be replaced with:
range	induction range
furnace	mini-split heat pump
clothes dryer	heat-pump clothes dryer
water heater (tank)	heat-pump water heater (tank)

Other hydrocarbon load:	Could be replaced with:
ICE car	electric car

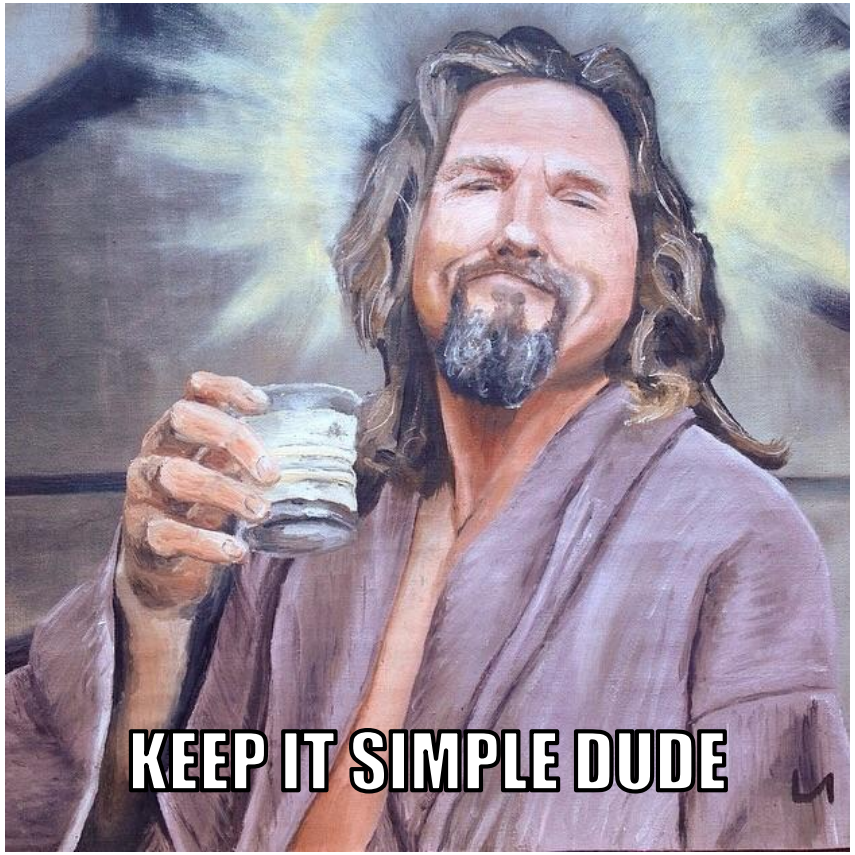
Why offer electrification?

Remove the gas-vent pipes.

...To increase available roof space.

And install prettier arrays.

Business case against proposing electrification



Induction cooktop

An appliance that uses electromagnetic fields to make heat in cookware.

Image: WebstaurantStore

Induction cooktop

The cookware must have enough iron atoms to create a magnetic field.

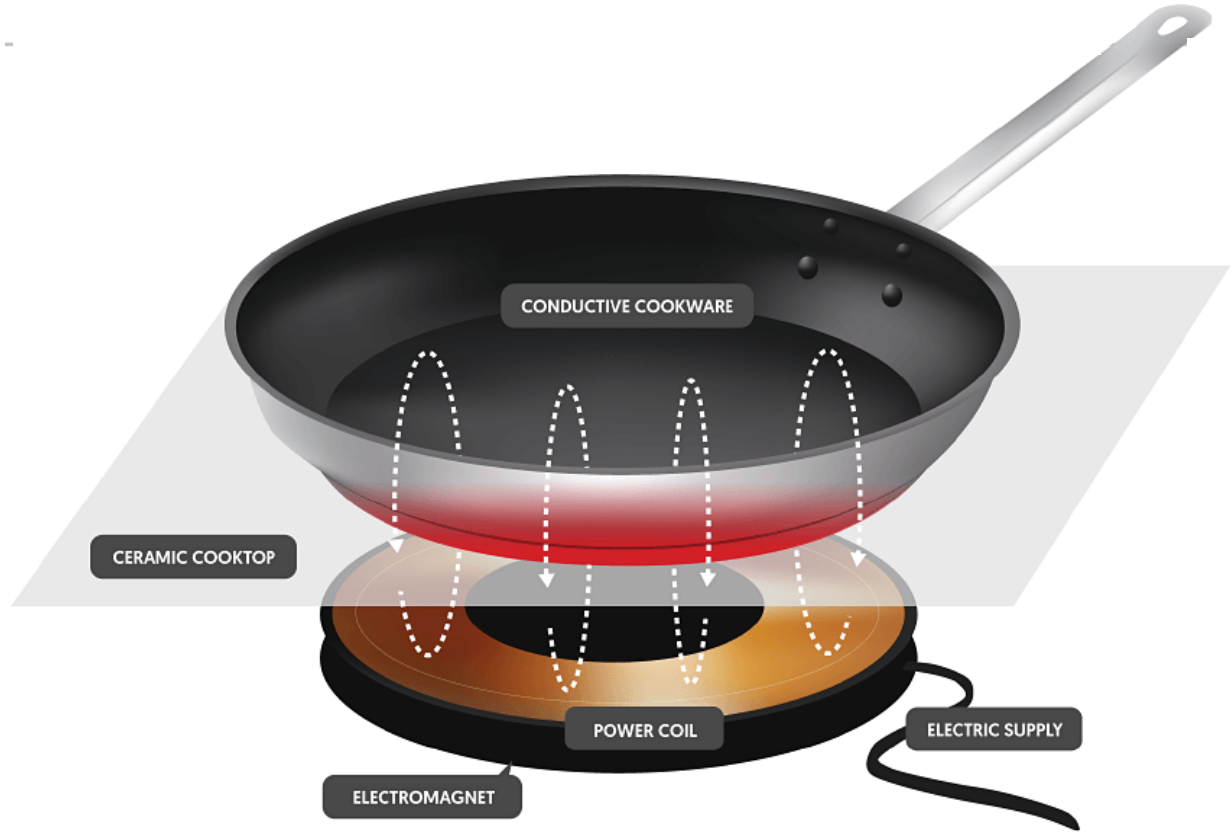


Image: [WebstaurantStore]

Find a good user experience

...Look for more heat-setting granularity and intuitive control.

Image: Fast Company

Consider lending out portable cooktops

Let your prospects try this new-fangled technology.

Induction ranges with built-in batteries

One option has a 4 kWh battery.

...It can be plugged into a 120-volt circuit.

Image: Copper

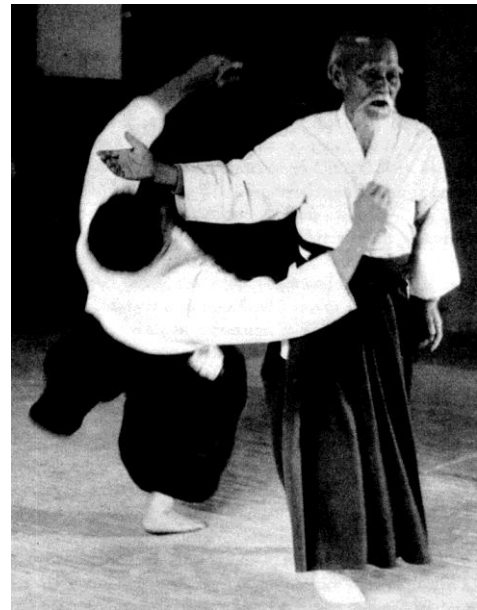
Air-source heat pump

A system that can both heat and cool a building.

To heat a building...
It pulls heat from the outside air and dumps it inside.

To cool a building...
It pulls heat from the inside air and dumps it outside.

...So it's *moving* heat energy — not converting to it.



A heat pump is just an air conditioner…

That can go in reverse.

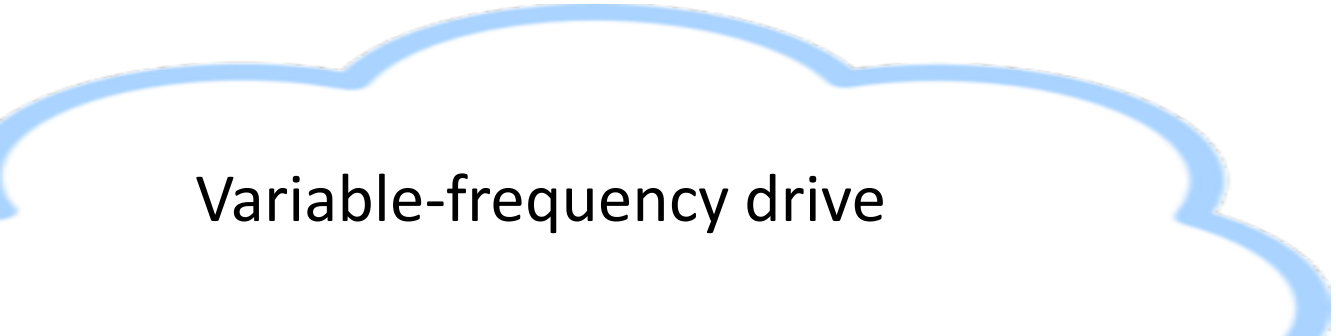
Heat pumps are better now

The technology has improved a lot in the last few decades.

Variable-speed heat pumps

Automatically adjusts the compressor speed to match the need.

...Lower in-rush current, better temperature control, and higher efficiency.



Variable-frequency drive

Heat pumps in the snow

Heat pumps can get adequate heat from sub-zero outside air.

They’re less efficient at colder temperatures, but much better than before.

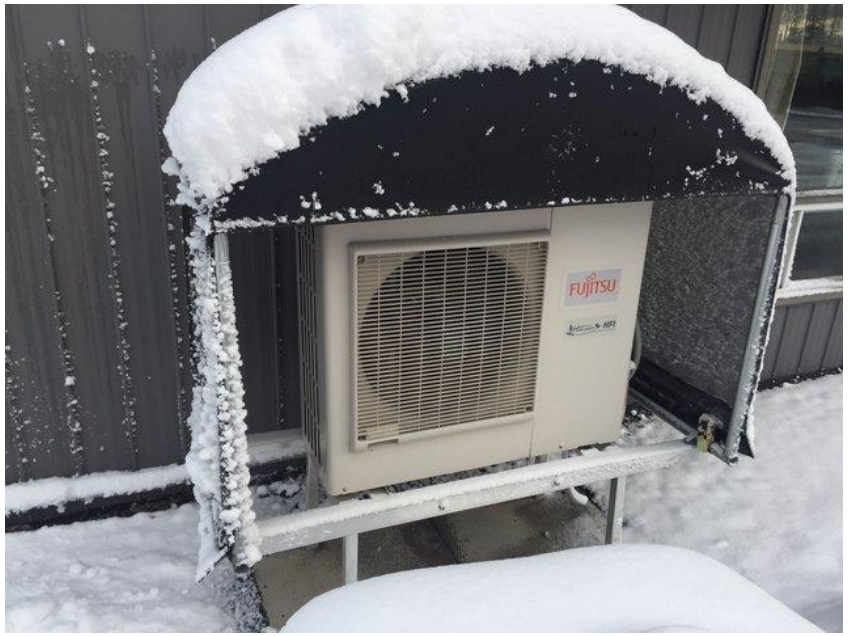


Image: Cover-Tech

How do heat pumps work?

Refrigerant

A fluid used in a refrigeration system to move heat.

...That changes phases at convenient temperatures and pressures.

CO2 refrigerants are cleaner than HFCs (hydrofluorocarbons).

Image: Cielo

Second law of thermodynamics

Heat moves from hotter to colder... until there’s balance.

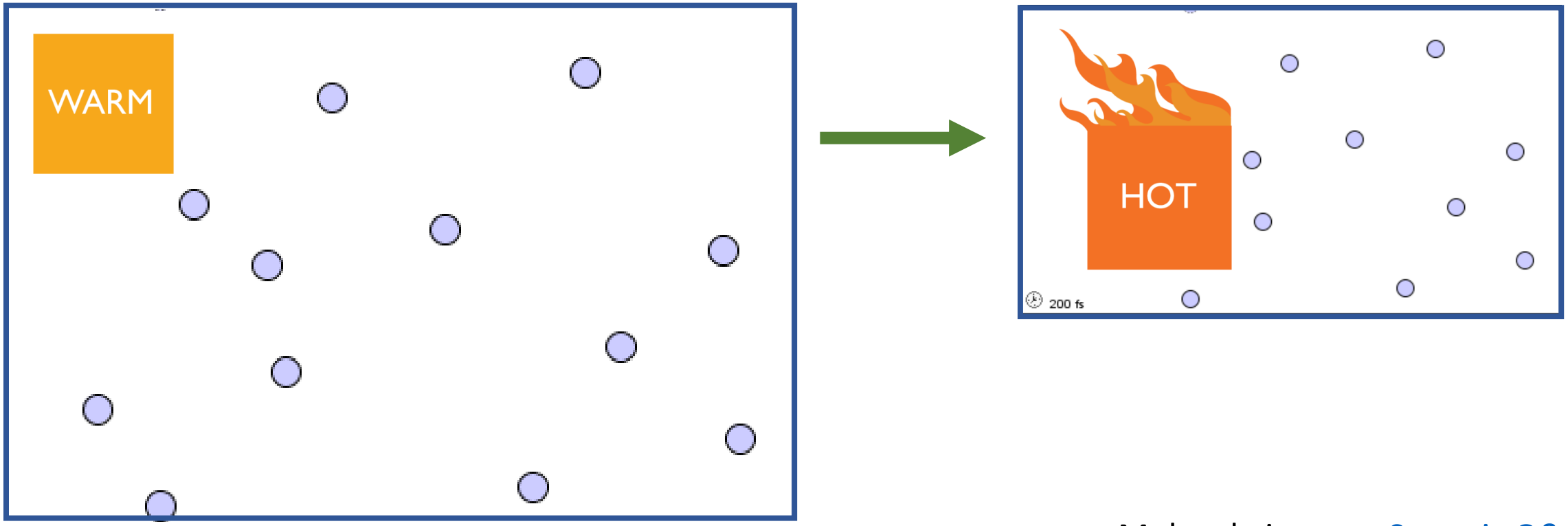
Evaporation

Liquid turns into gas.

Heat is absorbed by the gas in this process.

Compression

Increasing the pressure makes the gas hotter.



Molecule images: Socratic Q&A

The opposite of evaporation…

Condensation

Gas turns into liquid.

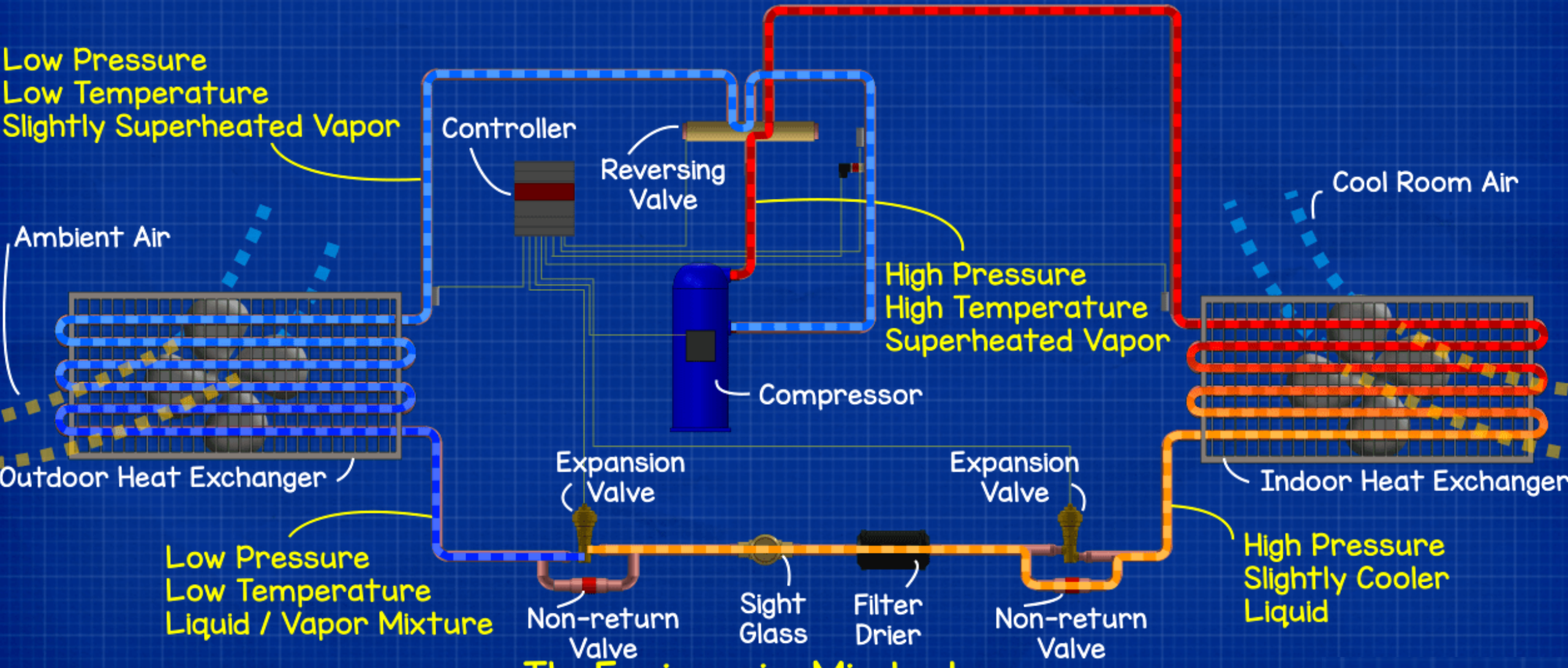
Heat is released by the gas in this process.

Expansion

Reducing the pressure makes the refrigerant cooler.

How Heat Pumps Work

Air to Air Heat Pumps



TheEngineeringMindset.com

Coefficient of performance (COP)

The moved thermal energy vs. the energy used to move it.

A range of COP ratings is given for specific air temperatures.

Heating / Cooling	Outdoor Dry Bulb	Indoor Dry Bulb	Unit	Min	Rated	Max
Cooling	95°F	80°F	COP	4.5	4.71	3.91
Heating	-5°F	70°F	COP	2.71	-	1.93

Images: NEEP Heat Pump List

Heat-pump water heaters

Image: [Electrify Now]

Energy Factor

COP, but for heat-pump water heaters.

Heat-pump clothes dryers

Image: Generation180

Mini-split heat pumps

Image: ECI Comfort

Ducted heat pumps

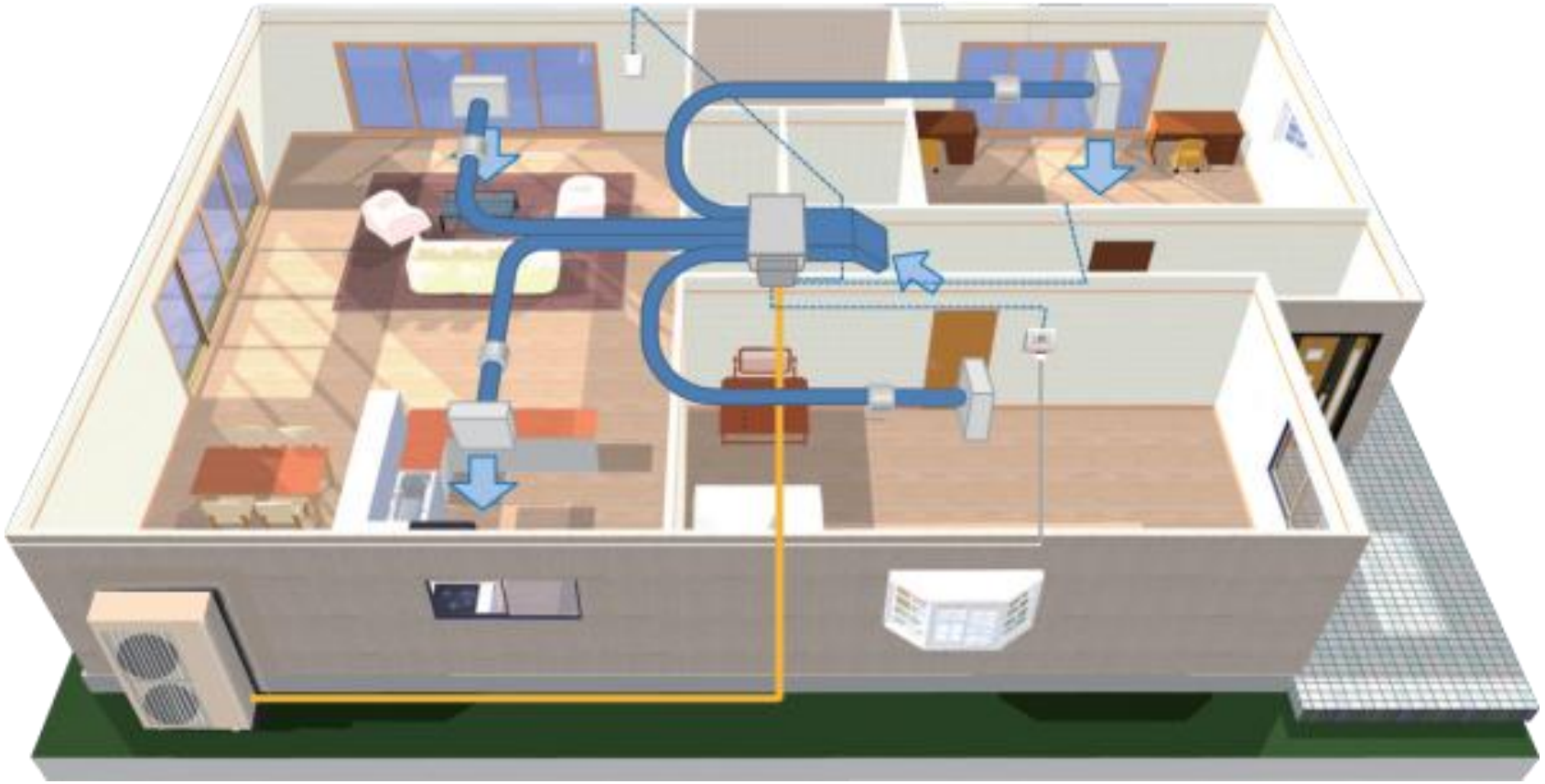


Image: Heat Pumps Now

Combined water-and-air heat pumps

harvest thermal

Image: Harvest Thermal

Power control and heat pumps

The PCS should know how to protect compressors.

...Compressors need a few minutes before getting turned back on.

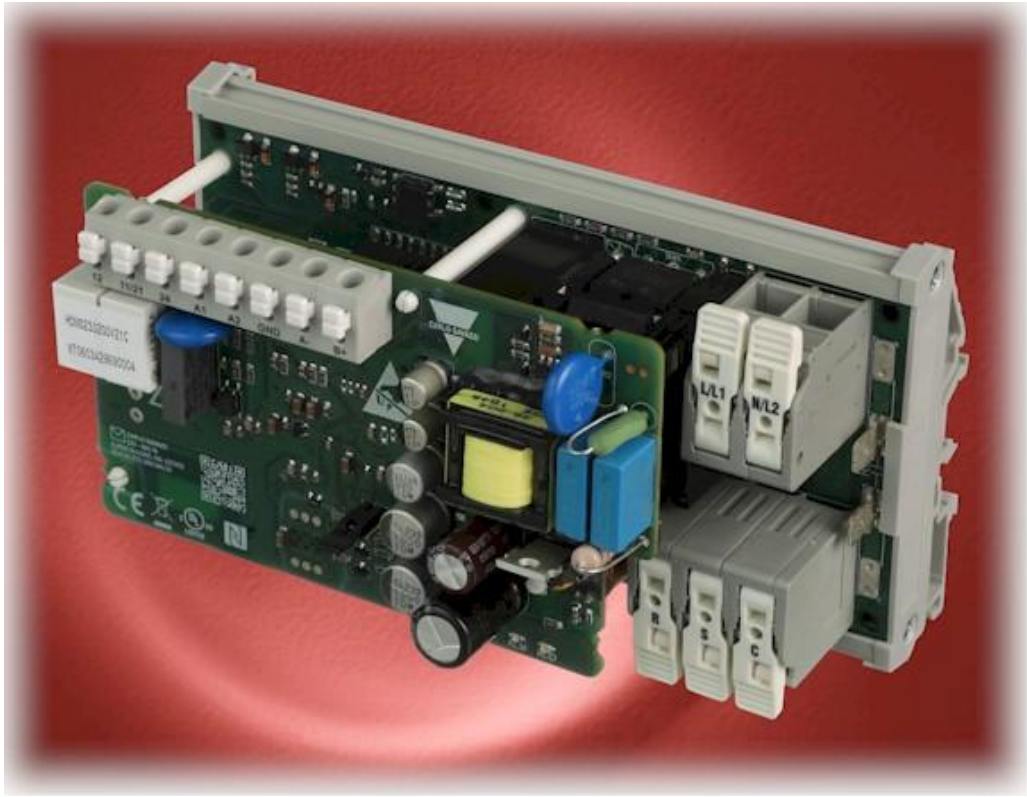
Energy Recovery Ventilator (ERV)

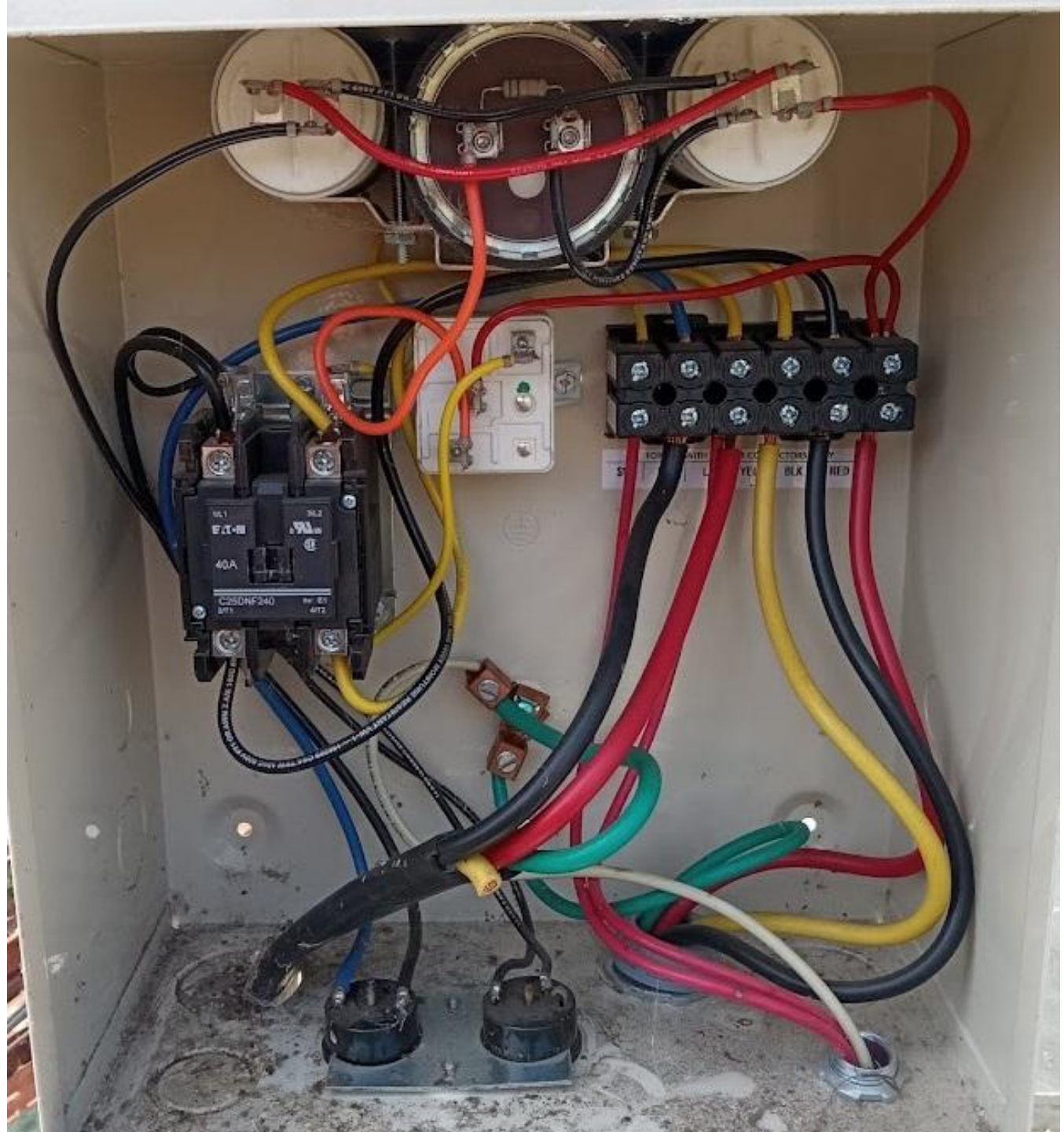
Transfer heat and moisture when pulling in outdoor air.

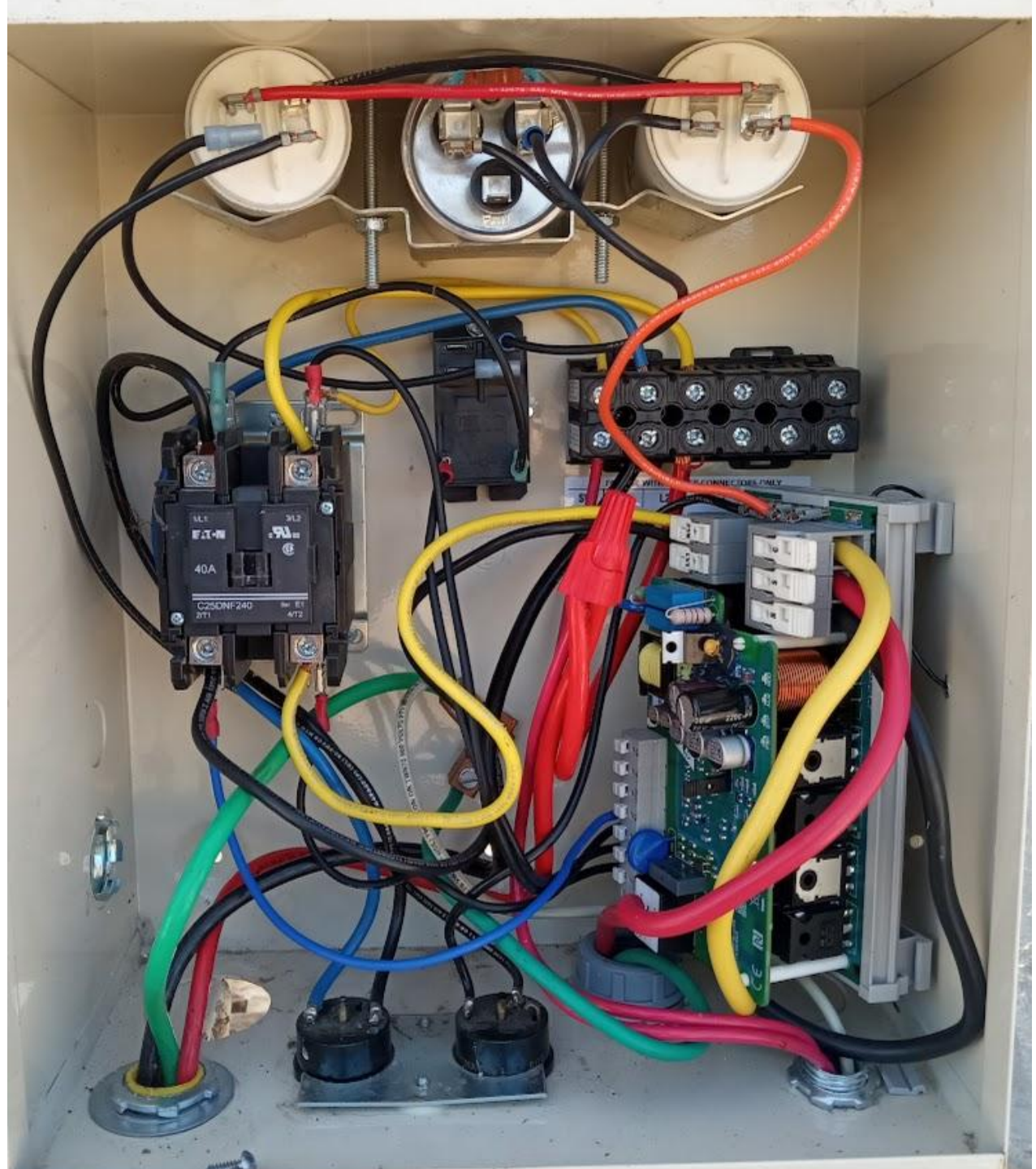
Image: Westland

Soft starters

Reduce the in-rush current of fixed-speed motors.

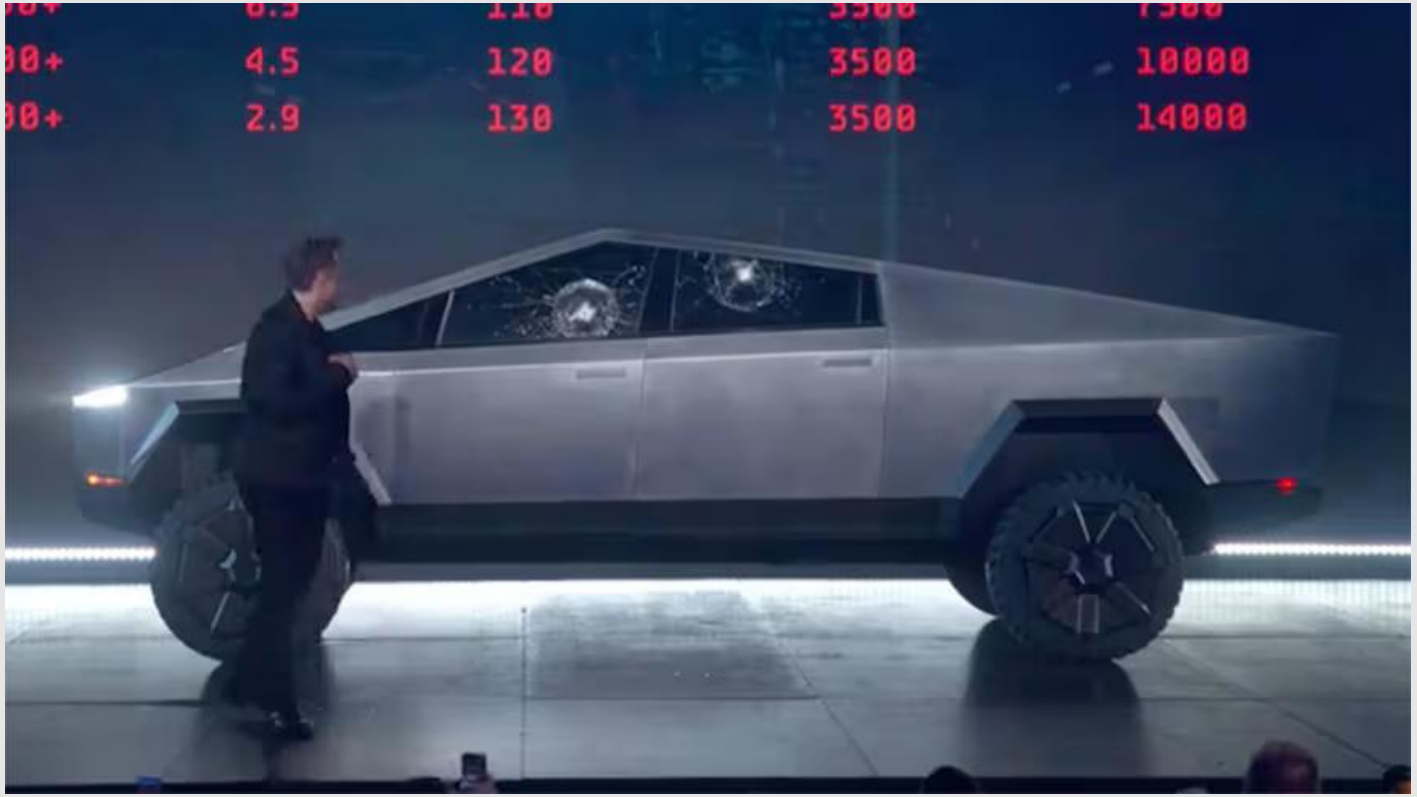



40A
C25DNF240


40A
C25DNF240

Electric car

Electric car



Tesla Cybertruck

Electric car

Nissan Leaf

Electric car

A car that’s 100% powered by electricity.

Electric Vehicle (EV)

Image: EMF

AC charging

Supplying AC power to an electric car.

Level 1: 120-volt power

Level 2: 240-volt power

The car’s integrated converter changes the AC power to DC power.

An AC connector standard: SAE J1772.

DC fast charging

Supplying DC power to an electric car.

The EVSE directly charges the car battery.

A DC connector standard: Combined Charging System (CCS)

Bidirectional (DC) charging

The EVSE supports EV charging *and discharging*.

(And the local AHJ allows it.)

Vehicle to Home (V2H)

Export power from the electric car...

For use in the home (with or without grid availability).

Image: Ford

Vehicle to Grid (V2G)

Export power from the electric car...

For use somewhere else on the grid.

Image: [Renault Group]

Vehicle to Everything (V2X)

Export power from the electric car...

For use at the site or elsewhere on the grid.

Not much V2X in the U.S. yet

Some car-company warranties don’t allow it.

There are safety concerns around backfeeding the grid.

Not much V2X in the U.S. yet

Some car-company warranties don’t allow it.

There are safety concerns around backfeeding the grid.

But soon.

Image: Sigenergy

Dynamic PV charging

Pass extra PV power to the car instead of exporting to the grid.

Heat pumps in electric cars

Many electric cars now use heat pumps.

These improve the battery's performance and increase range.

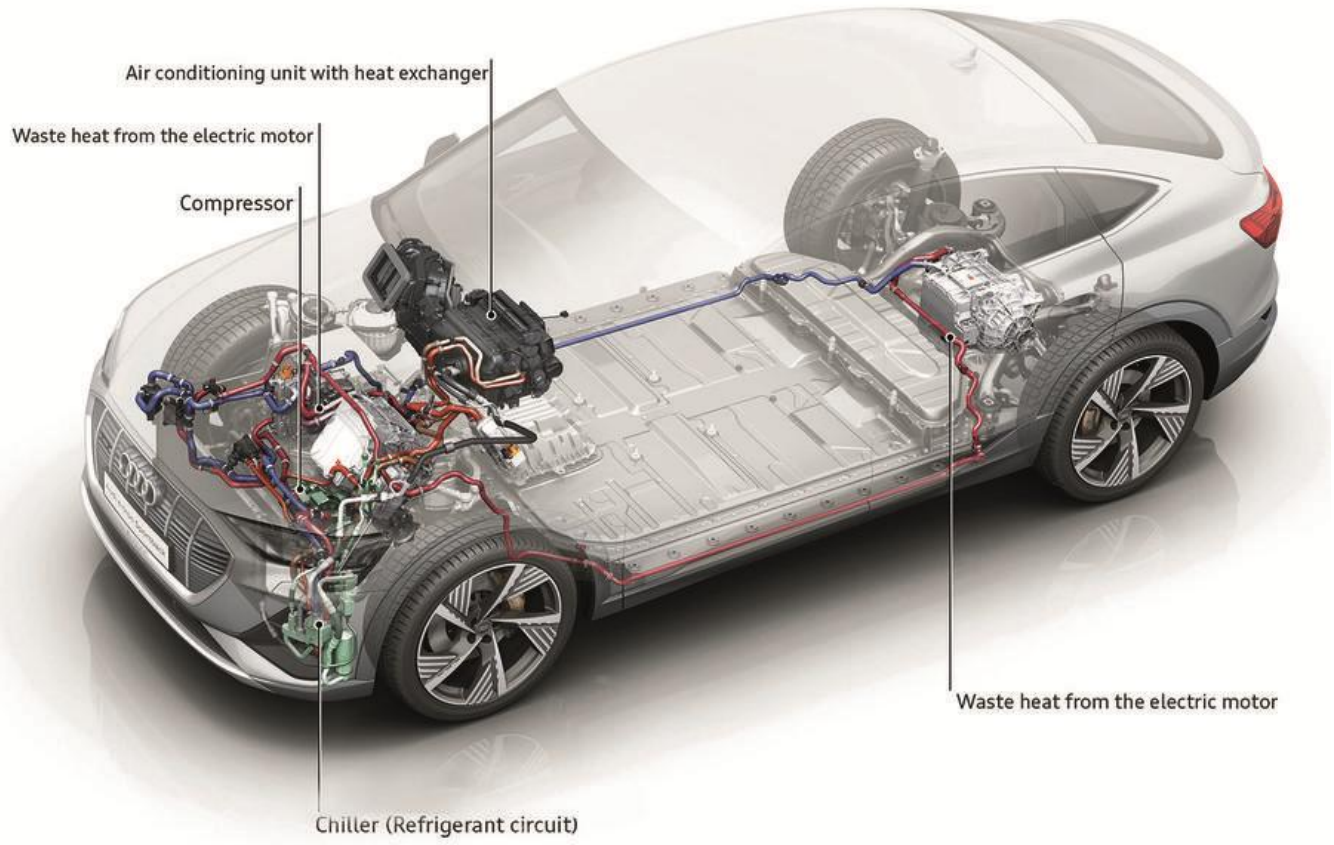


Image: Autocar

Islanding

Site disconnection from the grid, temporarily...

While using on-site power sources to run some or all site loads.

Battery backup

Microgrid

A group of (adjacent) sites that can island together.

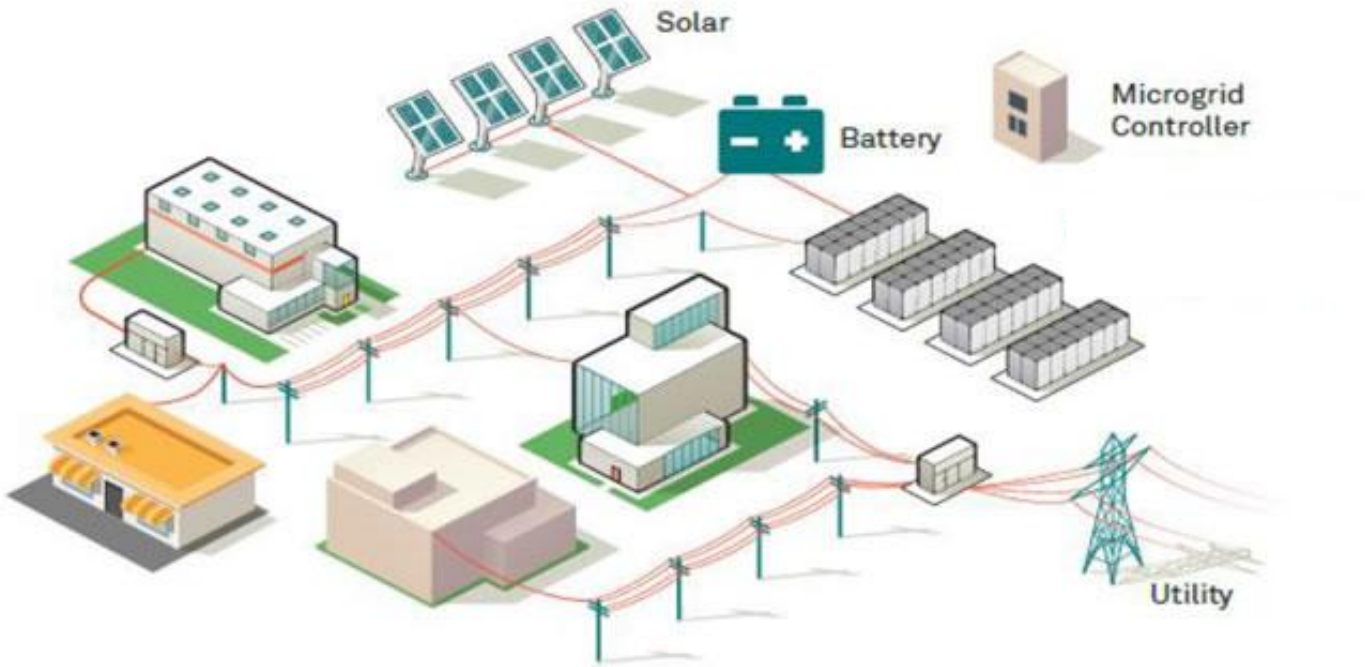


Image: Bloom Energy

Does the prospect want their own (energy) island?

If so, will you model and propose that?

Island in a box

Just add more solar and batteries.

Easy right?

Full-site islanding thru batteries

It probably costs too much.

And a large degrading battery bank is a future complication.

Critical-load islanding thru batteries

This is probably inconvenient and unsatisfying.

Air conditioning is typically unavailable.

Can we make full-site islanding practical?

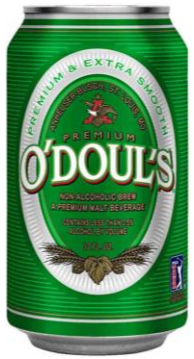
Step 1

...for practical and affordable full-site islanding...

Get the easy wins

Example: The old energy-hog fridge in the garage with three things in it.

...That hasn't been opened in months.



Step 2

...for practical and affordable full-site islanding...

Use the site’s existing energy-storage system

Your prospect already has one or two “lying around.”

Vincent Vega can’t find the energy-storage system.

Recall this slide:

Energy storage can be electrochemical, gravitational, or thermal.

Gravity-system image: EDN

A building is a thermal energy-storage system

A water-heater tank is too

Flexible-load control

Load flexibility is the giant nobody is talking about.

— Jigar Shah

Flexible load

A load that can be used earlier or later than otherwise.

Or a load that can draw less power than otherwise.

...Without impacting occupants.

Flexible-load examples

Dimmable lighting

EV charging

Pool cleaning

Air heating & cooling (think pre-heat/cool)

Battery charging

(What else?)

Water heating

Flexible-load control

Adjust a load’s timing or power level, to leverage its flexibility.

...To the extent this doesn’t impact occupants.

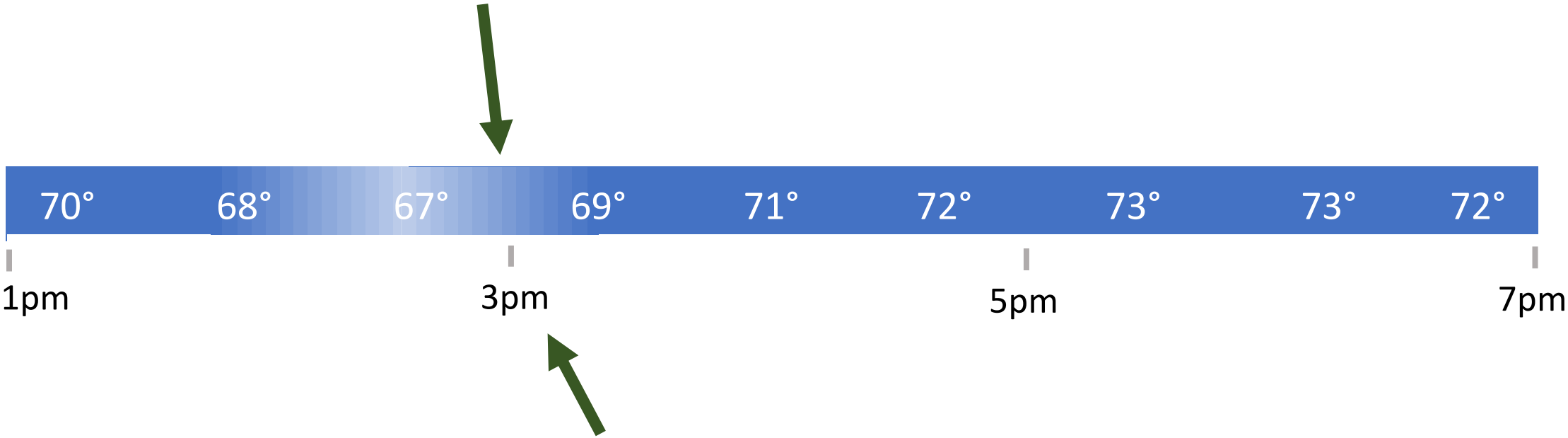
Consider air cooling

The home's PV power exceeds its total load until around 3pm.

It's pretty darn hot until around 6:30pm.

Precooling!

Convert some or all extra PV power to cooler air, until 3pm.



Turn off the heat pump (or AC) at 3pm.

How big is this thermal-storage system?

If the heat-pump load is 3.4 kW...

And 1.5 hours of air conditioning was moved earlier, into the solar window...

 ...

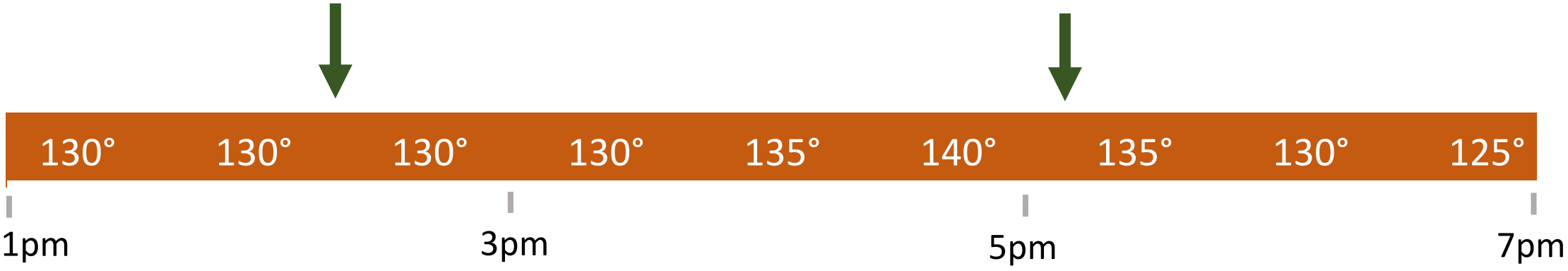
That’s a 5.1 kWh energy-storage system.

The same logic goes for preheating

...of both air and water.

Raise the water-heater temp at 2:30pm

Start showers and baths



This is a non-residential thing too

A software company exists to support non-residential flexible-load control.

ELEXITY

Thermal energy-storage system efficiency?

We need to know this, to plan accordingly.

Blower door

A tool used to measure the air tightness (or leakiness) of a building.

Image: InspectorTools

Blower door number

The blower door’s air-leakage reading.

...The amount of air the blower door needs to pull in, to keep the building’s air pressure at 50 pascals.

Measured in cubic feet per minute (CFM).

Image: Energy Smart

Blower door number

Every 10 points is roughly equal to a square-inch hole.

4,000 CFM/50 → ~ 400 square inches

400 / 144 square inches per foot = almost 3 square feet

That's about — 6 — basketball-sized holes.

Source: Nate Adams

Blower door test

The blower door number is by far the most important number I want to know about a house.

Given the choice between square footage, year built, energy use, number of occupants, or blower door number, I want to know the blower door reading.

Every. Single. Time.

— Nate Adams

From Nate’s book: Home Comfort 101

Let’s say the house is leaky

Image: Grist

Air sealing and insulation work?

No way, I’m not an insulation contractor!

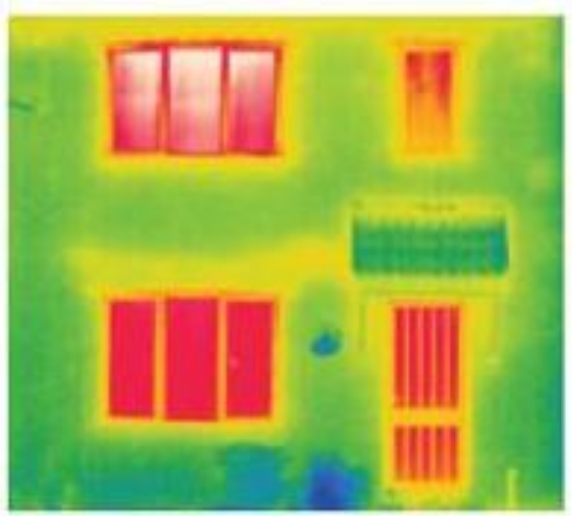
Okay! Maybe find a subcontractor.

Where are the biggest air leaks?

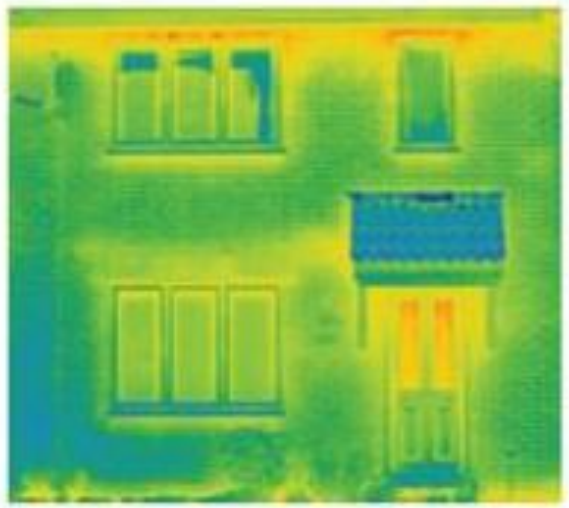
A thermal camera will help identify them.

Image: U.S. DOE

Before and after



Old windows



New windows

Images: Earth Sense and Fiona Thomas

Before and after

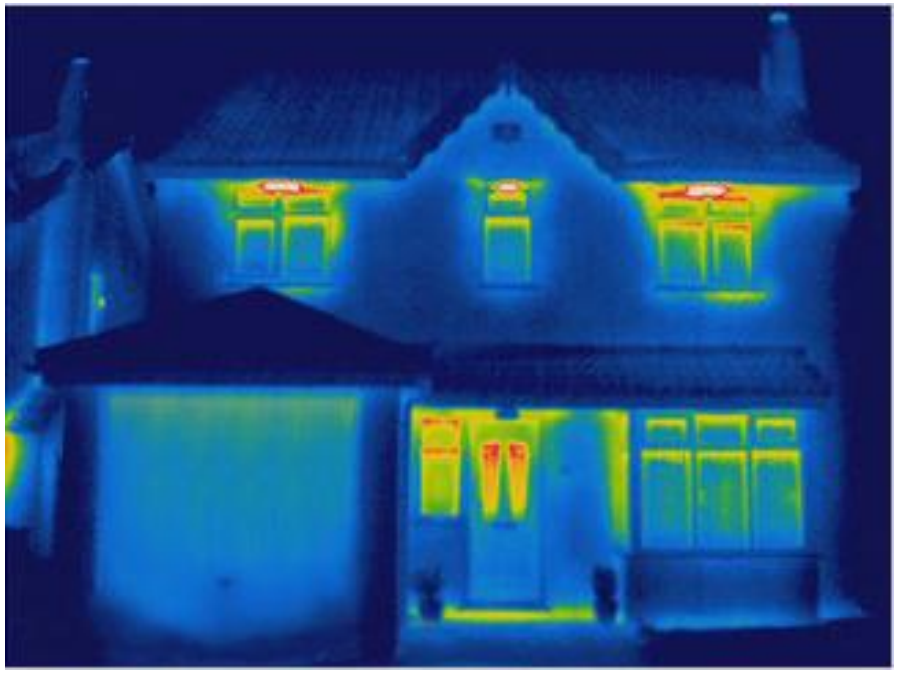


Image: NY Times

Before and after

4,000 CFM/50

1,700 CFM/50

Air sealing and insulation is durable

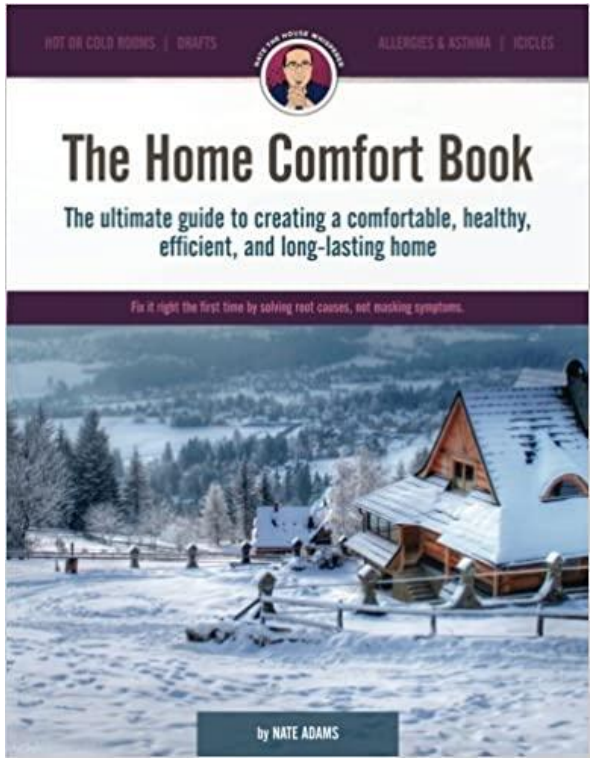
No moving parts. No electrochemical reactions.

...This strategy supports long-term ease.

Building performance

The art and science of making a building more comfortable, healthier, longer lasting, and more efficient.

— Nate Adams



Quote: The Home Comfort Book

Some other priceless benefits come free:

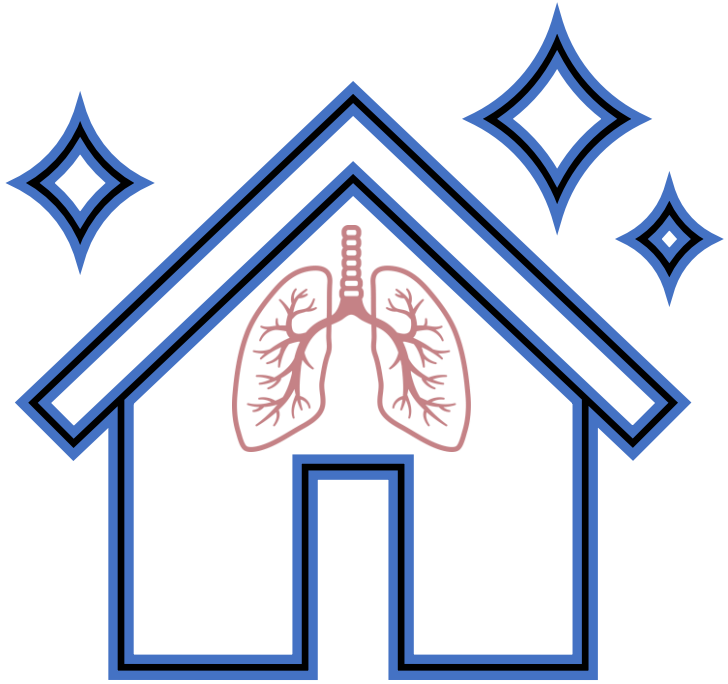
A more comfortable space.

- Less drafty.
- A consistent temperature throughout.

Easier air-quality management.

Easier humidity management.

- A mold-free environment.
- A longer-lasting building.



Create the Usage Profile

Energy usage profile

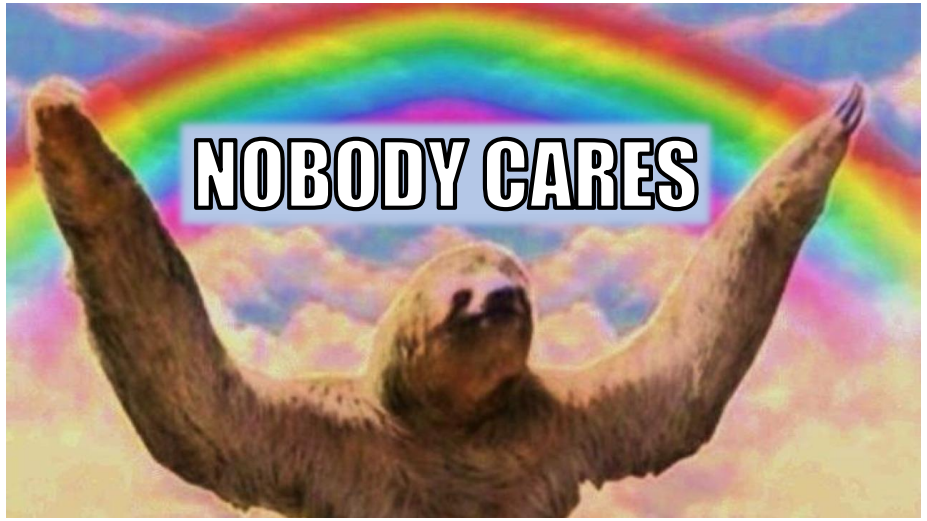
The interval-by-interval energy usage totals over some time period.

In a model, the profile’s duration is typically one year.

How do we get an energy-usage profile?

Use the latest 12 months of interval data?

…This is a lot more diligent than monthly-usage totals.

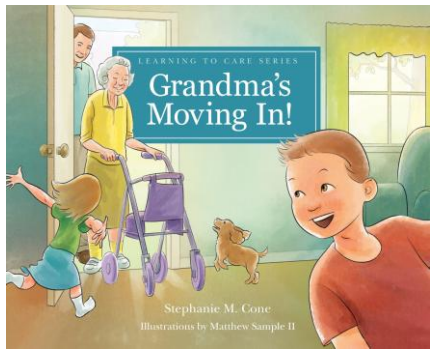


Complication:

The utility customer’s historical usage… is history.

People change, and sites change. Sometimes dramatically.

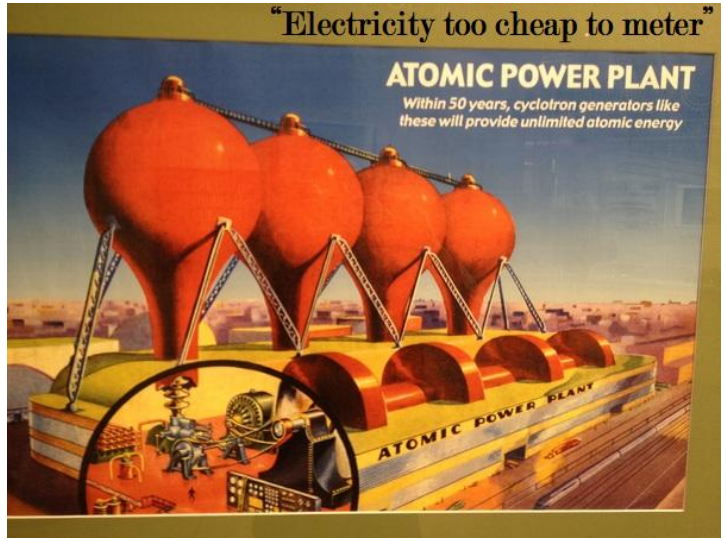
What near-term changes are anticipated?



Anticipated electrification work?

And what about their response to…

FREE POWER on their roof?



Or… a radical new energy consciousness?

Ability to island?

To properly size the PV and batteries...

Model each major load independently.

And run different scenarios, with load flexibility accounted for.

Complications

Lifestyle changes

Air sealing and insulation work

Electrification

FREE POWER psychology

Islanding capability

We need a synthetic energy model

Model:

> A simplified mathematical description of a system, to assist calculations and predictions.

We'll use this model to create a synthetic energy usage profile.

Based an Oxford Languages definition.

Doing this right takes time (or legit software)

As a society, we have gotten used to free quotes. Except they're not free. We pay for them with lower quality.

If you had to give 3-6 bids to get a job, would you put hours of unpaid work into each bid? Not if you intended to stay in business!

— Nate Adams

From Nate's book: Home Comfort 101

Survey the prospect

Ask about anticipated lifestyle changes.

Gauge interest in:

- electrification options
- islanding support

Outline the anticipated building schedule going forward.

(This is an invitation to start a healthier and more fulfilling schedule.)

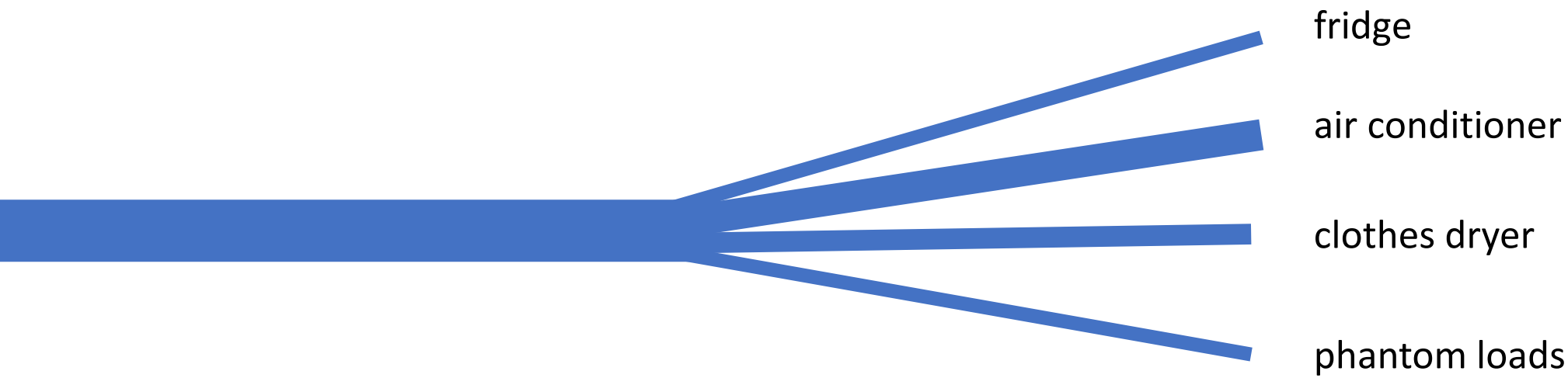
Get on the same page

Because if they like to run the AC with all the windows open...

Your energy model should know that.

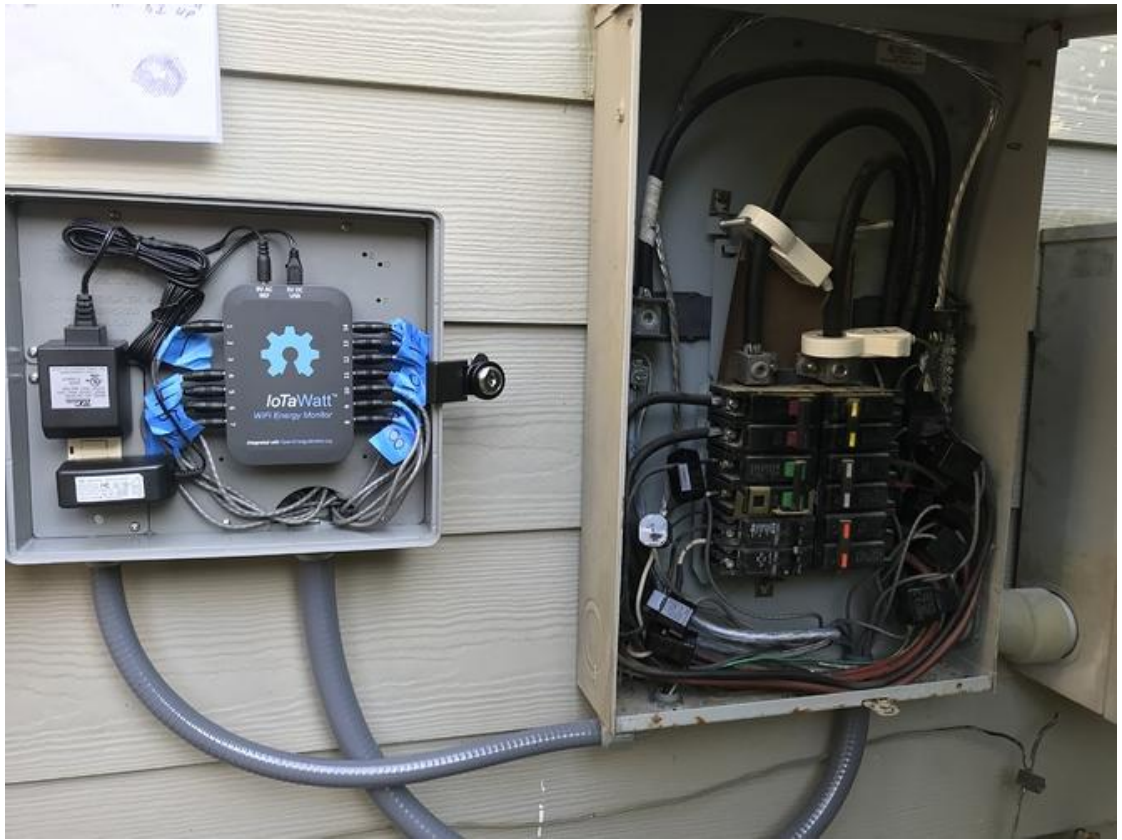
Load disaggregation

Separate the site’s total load into its individual loads.



Load-power monitoring

Circuits can be monitored at the electrical panel.



Current transformer (CT)

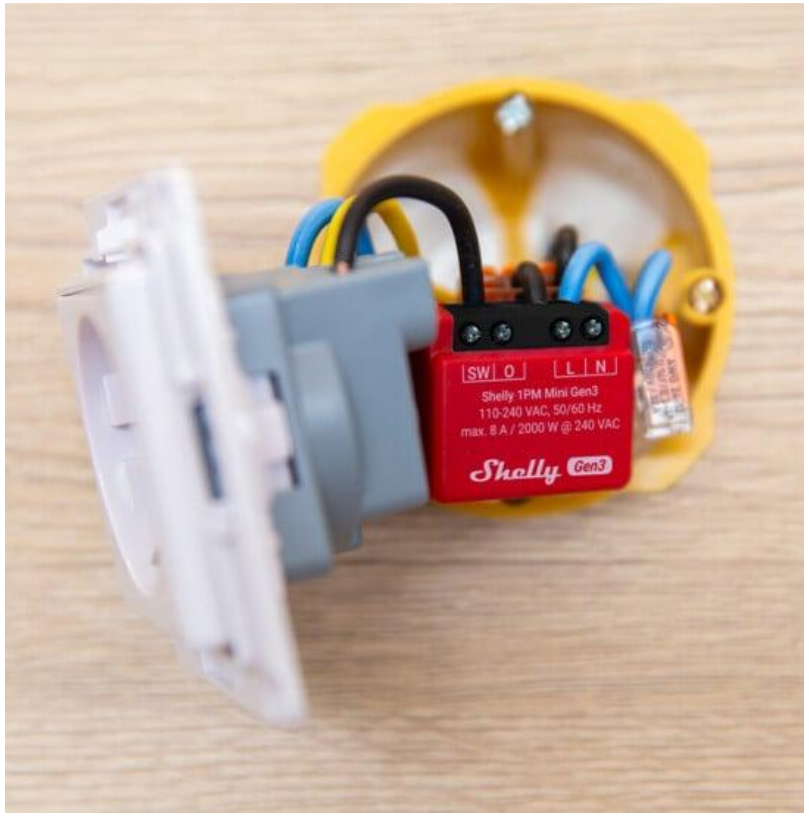
A device that derives a wire’s current flow from its magnetic-field strength.

Only works for AC power.

Image: TechHive

End-load monitoring

There are network-connected relay switches and smart plugs.



Choose the target loads to monitor

Examples: The air conditioner, the refrigerator, the pool pump.

Monitor existing loads for a full year?

Maybe. Or extrapolate, using data from a shorter time period.

...Taking outdoor air temperature into account if applicable.

Load monitoring after installation

Compare target-load projections to actual performance.

Improve your model accordingly.

What about natural-gas loads?

To project the energy-bill difference with an electric option...

First model the business-as-usual natural-gas load cost.

Disaggregate natural gas loads?

This probably isn’t practical at residential and small non-residential sites.

...Because pressures are so low.

Plan to just estimate the cost of targeted natural-gas loads.

Create load profiles for new electric loads

Example: A mini-split heat pump

Model inputs: square footage,
the blower-door reading,
anticipated occupant preferences and behavior,
outdoor air temperature,
building's sun exposure,
PV-array roof shading

With data in hand, do the modeling

Better yet, let computers do the modeling

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