Zero Carbon, Zero Bills

How to cut your home’s carbon footprint, heating bill and electricity bill to zero

By someone who has done it: David Green
Today’s logistics

• All participants will be muted during the presentation.
• To ask a question or make a comment, please type your question or comment in “chat”. The MC will monitor questions and relay them to me. There will be a 5 minute break for Q&A after every section
• At the end we will allow participants to unmute themselves so that you can ask questions live
• I will stay on until the last attendee’s question gets answered
• The webinar is being recorded
About the author, David Green:

• Holds a degree in physics from Oxford University (with honors)
• And an MBA from Harvard Business School (with distinction)
• Founded, and was CEO of, two biotechnology companies: Harvard Bioscience™ and BioStage™. He took both companies public.
• While at home recovering from a 2014 road accident he did the research on cutting his family’s carbon footprint.
• His house and pool now have a zero-carbon footprints.
• He is saving over $11,000 a year on house bills and $3,000 on the pool
• He is the author of Zero Carbon® Home and Zero Carbon® Pool
• He does not work or get paid by any manufacturer, installer or town
• He has no financial conflict of interest, other than selling the book for $25/$15. He consults to homeowners wanting to “go zero” but usually gets paid on results – 1x the actual first-year energy bill savings
• His advice is based on his experience but neither he nor Zero Carbon LLC is giving investment, tax, legal or financial advice, nor providing any guarantee of results
• I’m not going to tell you to eat vegetarian, turn down your thermostat, wear a cardigan, bike to work, have fewer children or vote for Al Gore
• It is coincidence, or perhaps destiny, that our family name is Green.
How was the data gathered?

• Our house is a 2-story, 5,400 sf house built in 1974 with 4” cavity walls filled with fiberglass.
  – Before we “went zero”, it had no energy efficiency features
  – We live in Dover, Massachusetts with 5,800 HDD
• Each day for over 2 years I have measured the heating oil and electricity used by our home
  – I used this data to build an energy model of our home with over 80% R-squared daily. Full-year bills projected +/- 10%
  – I used the energy model to make financial projections of the changes to our home – cash-flow based NPV, IRR, payback
  – I measured the cut in energy and $ for each of the fab four
  – Similar method for our rental property and consulting clients
Why now?

Because the technologies of insulation, heat pumps, solar panels and triple-glazed windows are now so good and the subsidies from government are so significant, you can, by following these examples, cut the carbon emissions from your home to zero, save thousands of dollars a year on heating and electricity bills, and make a good return on your investment.

We have done it.

(it works on new houses too and for renters)
Fab Four

How did we cut our carbon footprint to zero? By installing the fab four:

• Heat pumps
• Insulation
• Triple-glazed windows
• Solar panels

Easy to remember the fab four because the Fab Four (The Beatles) had lots of HITS

How did we go zero and make money? By installing the fab four and getting all the tax breaks and subsidies
HITS - Heat Pumps
## Results for Heat Pumps

<table>
<thead>
<tr>
<th>Effect on</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Footprint</td>
<td>Cut 47% (20 tons)</td>
</tr>
<tr>
<td>Money saved per year</td>
<td>$2,888</td>
</tr>
<tr>
<td>Investment (net)</td>
<td>$26,250</td>
</tr>
<tr>
<td>Years to pay for itself</td>
<td>9.1</td>
</tr>
<tr>
<td>Return on investment</td>
<td>9% (after tax)</td>
</tr>
</tbody>
</table>

In addition, in an October 2020 article in the journal Nature Energy, the researchers reported a 4-7% price premium for houses with heat pumps compared to similar houses without heat pumps. On an average house, this translates to a premium of $10,000 to $17,000, or roughly what heat pumps would cost on an average house. This means you no longer have to wait for the payback period to get your money back on heat pumps – you get it back as soon as you sell your house.
Our heat pumps replaced our AC units, but both heat and cool the house.

Heat pumps heat with 2.5x the efficiency of a furnace or boiler and cool with the same efficiency as an AC unit.
A heat pump cools your refrigerator by pumping the heat into the kitchen.

Heat is removed from your refrigerator making it cooler.

Heat is dispersed to your kitchen air making it warmer.
A heat pump cools your house in summer by pumping heat to the outside air.

Heat is removed from your house by the AC unit, cooling your house.

Heat is dispersed to the outdoors air making it warmer.
A heat pump warms your house in winter by pumping heat inside.

Heat is moved into your house by the heat pump, warming your house.

Heat is removed from the outdoors air making it cooler.
Heat pumps make the outside air even colder in winter
Wall or Ceiling-Mounted Heat Pumps
(Aka Ductless Mini-Split Heat Pumps)

Outdoor condenser unit

Indoor ceiling-mounted unit
HITS - Heat Pumps

• For details on subsidies available and zero-interest loan financing see Ch. 2 in the book
• I do not recommend geothermal (ground-sourced) heat pumps, unless: cheap wells, 26% FITC, $2,000/ton (up to $15,000) MassSave rebate if on oil or propane
• ASHPs work with radiators/forced hot-water too, and by using existing AC ductwork
• And swimming pools and hot-water tanks
• Leave your furnace in place
• Get multiple quotes

• Any questions so far?
Questions to ask a heat-pump installer

- Does the Manual J show my house will be at 70°F when it is 5°F outside?
- If you have no ductwork ask, “Can you quote this 1) with ductless units and 2) with ductwork in the basement for the ground floor plus ductwork in the attic for the upper floor?” Also ask for a quote for radiant-floor heating, this was surprisingly cheap in our rental house (but this will not do AC for you). Make sure the attic work is well insulated or you will get ice dams.
- I have not tried AC using cold water in radiators. Some manufacturers say it can be done, but I doubt it without getting pools of condensation on the carpets.
- For forced-hot water radiators, make sure the Manual J calculation is done with a water temperature of 110°F not 140°F
- How much money will I save on heating if I am paying 23c/kWh for electricity? How much if I am paying solar rates (5-8c/kWh)
- How much for a heat-pump hot water tank? How much will it save me per year?
- How long is the warranty, does it cover parts and labor?
HITS - Insulation
## Results for Insulation

<table>
<thead>
<tr>
<th>Effect on</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Footprint</td>
<td>Cut 16% (7 tons)</td>
</tr>
<tr>
<td>Money saved per year</td>
<td>$2,923</td>
</tr>
<tr>
<td>Investment (net)</td>
<td>$1,000</td>
</tr>
<tr>
<td>Years to pay for itself</td>
<td>0.3</td>
</tr>
<tr>
<td>Return on investment</td>
<td>100% (after tax)</td>
</tr>
</tbody>
</table>
Insulation: what we did

Our flat roof

10” fiberglass plus 4”
ISO board – R50 total

Our basement ceiling

12” fiberglass –
R38 total
Insulation + Air Sealing

• Air sealing is cheap and can cut energy use 25%
  – My clients’ experience
  – DoE says average house loses 30% thru gaps and cracks

• A major academic study found that insulating attics in row houses cut energy use 8% but insulating and air sealing cut it 18%

• Most houses need air sealing and insulation

• It is not necessary to get to Passive House levels of air infiltration (0.6 ACH50) to get to zero carbon. My house is 4.6 ACH50.
  – Getting to PH levels of air infiltration is unnecessary, expensive (ERVs cost $5,000), and can be unhealthy
Insulation - MassSave

MassSave will pay 75% of the cost of insulation up to $2,000 and 100% of the cost of draft sealing. They will not pay for spray foam.

Insulation is the lowest hanging ripest fruit in the garden. Pick it!
HITS - Insulation

• For details on which type of insulation to put where in your house, occasions to insulate walls opportunistically, how much of it to install and where to get the subsidies see Chapter 1 in Zero Carbon® Home. Or www.dsireusa.org

• I do not recommend you take off your siding, thicken the walls with insulation and replace your siding. It will cut your carbon footprint but it is far too expensive compared to insulating your roof and basement.

• It is not necessary to get to Passive House levels of air infiltration (0.6 ACH50) to get to zero carbon. My house is 4.6 ACH50. 10 is common, old drafty houses are 20.

• Any questions on insulation and air sealing?
HITS - Triple-Glazed Windows
Results for Triple-Glazed Windows

<table>
<thead>
<tr>
<th>Effect on</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Footprint</td>
<td>Cut 5% (2 tons)</td>
</tr>
<tr>
<td>Money saved per year</td>
<td>$974</td>
</tr>
<tr>
<td>Investment (net)</td>
<td>$4,500</td>
</tr>
<tr>
<td>Years to pay for itself</td>
<td>4.6</td>
</tr>
<tr>
<td>Return on investment</td>
<td>19% (after tax)</td>
</tr>
</tbody>
</table>

Note: the investment and cost savings are the additional cost above that for double-glazed equivalents. I only recommend you install triple-glazed windows when you are replacing your windows for other reasons like they are rotting or leaking. Replacing windows, any windows, will not usually pay for themselves from the utility bill savings. Unless you use “fit-from-the-inside” triple-glazed windows.
HITS - Triple-Glazed Windows

Our 1970’s double-glazed, metal framed windows with the gaps sealed with duct tape
HITS - Triple-Glazed Windows

In addition to cutting our carbon footprint and saving us money, our new wood-framed, triple-glazed windows have transformed the look and feel of our house – and we can see the garden!
How Do Triple-Glazed Low-E Windows Work?

- **Ultraviolet light** is reflected away to reduce solar heat gain and carpet fading.
- Infrared light is reflected back inside to keep you warm.
- Visible light enters the room to keep it light inside.

**Outside**
- Low-E 180 coating

**Inside**
- Low-E i89 coating

Example: How do UV light and infrared light work with Triple-Glazed Low-E windows?
Triple-Glazed Windows – It’s the Two Layers of Air That Insulate

Plus those low-E coatings that are a bit like an emergency space blanket
Low Cost, “fit-from-the-inside” Window Inserts

Window insert in single-glazed window.

Window insert in single-glazed window – 63F. Cost about $200, payback is about 5 years.

Single-glazed window, no insert – 40F
HITS - Triple-Glazed Windows

For details on how to:

• Shop for triple-glazed windows
• Which types of low-E glass I recommend for which locations; my evaluation of different window inserts
• How to get zero-interest loans to purchase them. If not in MA visit www.dsireusa.org
• I do not recommend the stretchy film, except as poor-man’s triple-glazed windows (get the free COVID19 edition on the web site)

Please see Chapter 4 in Zero Carbon® Home

Any questions on triple-glazed windows?
HIT$\!$ - Solar Panels
## Results for Solar Panels

<table>
<thead>
<tr>
<th>Effect on</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Footprint</td>
<td>Cut 32% (14 tons)</td>
</tr>
<tr>
<td>Money saved per year</td>
<td>$5,572</td>
</tr>
<tr>
<td>Investment (net)</td>
<td>$42,791</td>
</tr>
<tr>
<td>Years to pay for itself</td>
<td>7.2</td>
</tr>
<tr>
<td>Return on investment</td>
<td>13% (after tax)</td>
</tr>
<tr>
<td>Electricity cost (LCOE)</td>
<td>5-8c/kWh (ES 23)</td>
</tr>
</tbody>
</table>

In addition, the DOE/Appraisal Journal estimates (based on analysis of 49,000 houses with Census Bureau data over 5 years) that our house value has increased by $111,000 from installing the solar panels. PVValue/DCF estimate is $105,000. That is more than double our net investment in solar panels and more than our net investment in all the fab four.
How solar panels work

Positive and negative electrical leads carry DC power to the inverter.

AC power from solar panels flows to your meter.

Net meter records the electricity you used, less what you produced.

AC power to your house.

Solar panel made up of solar cells.

Inverter converts DC power to AC power.

Light coming from the sun.

AC power from utility.
Gross and Net Cost of our 17.6kW Array (Mar. 2017)

Gross cost $56,000

Federal tax credit -$16,900
MA tax credit -$1,000
Present value of MA SREC income -$23,800

Net cost $14,300

Cost per kWh 5c (ES 24c)
NPV (total profit) $29,000
IRR (return on investment) 14%
Breakeven 7 years

In addition the DOE estimates our house price increased $71,000
Recent bidding (under SMART) for a client was LCOE 4-6c/kWh.
I just bought two arrays with batteries at LCOE 6-8c/kWh
You don’t need to do DCF calculations yourself! Use the EnergySage web site which compares bids for you
HITS - Solar Panels

For details on how to:

• Perform the detailed technical and financial evaluation of both solar panel manufacturers and installers;
• Evaluate lease/loan/cash purchase options. (UMass5 bank is offering 4.5% interest. PPA rate is about 13c/kWh);
• Obtain subsidies and low-interest financing options. If not in MA visit www.dsireusa.org
• I do not recommend solar hot-water panels
• Towns’ price is about 10% less per W than what I recently paid
• Get multiple quotes, use EnergySage

Please see Chapter 4 in Zero Carbon® Home

• For batteries and their subsidies see my website

Any questions on solar panels?
Questions to ask a solar installer

• For how many years does the manufacturer guarantee the panel-power output?
  – Can I make a claim using only the data on the monitoring app, i.e., without having to get the panel independently tested?
• For how many years does the installer guarantee the array-energy production per year (in kWh/year)?
• What is the cost per kWh of the electricity guaranteed to be produced over the warranty period of the panels?
  – Cost should be after the federal and state subsidies
  – 5c/kWh is very good but even 10c/kWh is still a 55% cut and it is fixed
• What inflation rate did you use in the financial forecasts? If it is more than 3% ask them to redo the calculations. I used 0%.
• Did you allow for taxes on the SMART subsidy? SMART is taxable income.
• For how many years is my roof guaranteed against leaks?
The fab four – putting it all together

“All together now...”
from Yellow Submarine by the real Fab Four
Cost for the same amount of energy
From different heating fuels

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Cents/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>natural gas</td>
<td></td>
</tr>
<tr>
<td>heating oil</td>
<td></td>
</tr>
<tr>
<td>propane</td>
<td></td>
</tr>
<tr>
<td>electricity utility</td>
<td></td>
</tr>
<tr>
<td>electricity rooftop</td>
<td></td>
</tr>
<tr>
<td>solar- net cost</td>
<td></td>
</tr>
</tbody>
</table>

7/22/21
This is how we now heat our house – solar running heat pumps. This is now the cheapest way to heat your house.
The key to going zero

• Cut your house’s energy use so much you can generate it all from solar panels on your roof
  – Cut it with insulation and air sealing
  – Cut it with triple-glazed windows
  – Cut it with heat pumps
  – Generate it with solar panels

• This is the optimal order, not how I did it!

• Tenants: insulation, air sealing, window inserts?, HPHWT?, window-mounted or portable heat pumps, community solar, EVs and discuss solar with landlord
What are the safest and cleanest sources of energy?

### Death rate from accidents and air pollution

Measured as deaths per trillion hour of energy production. 1 trillion hour is the annual energy consumption of 27,000 people in the EU.

- **Coal**: 24.6 deaths, 1230 times higher than solar
- **Oil**: 18.4 deaths, 340 times higher than nuclear energy
- **Natural Gas**: 2.8 deaths
- **Biomass**: 4.6 deaths
- **Hydropower**: 0.02 deaths
- **Nuclear energy**: 0.07 deaths
- **Wind**: 0.04 deaths
- **Solar**: 0.02 deaths

### Greenhouse gas emissions

Measured in emissions of CO₂ equivalents per trillion hour of electricity over the lifecycle of the power plant. 1 trillion hour is the annual electricity consumption of 2700 people in the EU.

- **Coal**: 820 tonnes, 273 times higher than nuclear energy
- **Oil**: 720 tonnes, 180 times higher than wind
- **Natural Gas**: 490 tonnes
- **Biomass**: 78-230 tonnes
- **Hydropower**: 34 tonnes
- **Nuclear energy**: 3 tonnes
- **Wind**: 4 tonnes
- **Solar**: 3 tonnes

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*Life cycle emissions from biomass vary significantly depending on fuel (e.g. crop residues vs. forests) and the treatment of biogenic sources.*

*The death rate for nuclear energy includes deaths from the Fukushima and Chernobyl disasters as well as the deaths from occupational accidents in central stations.*

Energy shares refer to 2019 and are shown in primary energy substitution equivalents to correct for inefficiencies of fossil fuel combustion. Traditional biomass is taken into account.

Data sources: Markandya & Wilkinson (2007); Sovacool et al. (2014); IPCC AR5 (2014); Pehl et al. (2017); BP (2019); Snell (2017).

OurWorldInData.org – Research and data to make progress against the world’s largest problems.

Licensed under CC-BY by the authors Hannah Ritchie and Max Roser.
## Fab Four Summary

<table>
<thead>
<tr>
<th>Product</th>
<th>Total money saved (per year)</th>
<th>Total carbon footprint reduction (CO2 per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat pumps</td>
<td>$2,888</td>
<td>20 Tons</td>
</tr>
<tr>
<td>Insulation</td>
<td>$2,923</td>
<td>7 Tons</td>
</tr>
<tr>
<td>Solar panels</td>
<td>$5,572</td>
<td>14 Tons</td>
</tr>
<tr>
<td>Triple-glazed windows</td>
<td>$974</td>
<td>2 Tons</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$12,358</strong></td>
<td><strong>43 Tons</strong></td>
</tr>
</tbody>
</table>

Zero Pollution for the People.
Zero Carbon for the Planet.
Zero Bills for the Profit.
Zero Carbon New Houses

• I am working with a developer to build new zero-carbon homes that have zero bills, are healthy and comfortable.

• These homes have the lowest lifetime cost of ownership.
  – Which means the combined cost of the mortgage (including the additional cost of adding the fab 4), heating bill, electric bill and insurance.

• On a $450,000 house, my designs can save about $3,000 a year vs. a “code-built” house.

• Homeowners would probably pay $60,000 more for such a house just because of the zero bills.

• I would certify these houses and brand them Zero Carbon®.

• If you would like to collaborate to build these houses, please contact me at dgreen@greenzerocarbon.com.
Free “Zero Carbon, Zero Bills” Stuff:

A pdf file of the slides for this webinar,
A YouTube recording of a previous webinar,
Searchable, written Q&A from previous webinars,
And the free book are all available at:

www.greenzerocarbonhome.com

For the free iPad / Kindle copy of Zero Carbon Home,
visit my website and use the code ZCT. If this does not work, email me!

The paperback is not free.

For the free copy of the special “Stuck at Home COVID 19 edition”,
use the code COVID19

If you would like to collaborate on new homes email me at
dgreen@greenzerocarbon.com

Within a few days, I will email out the Q&A from this webinar