On the Path to Net Zero
A Westford Homeowners' Experience

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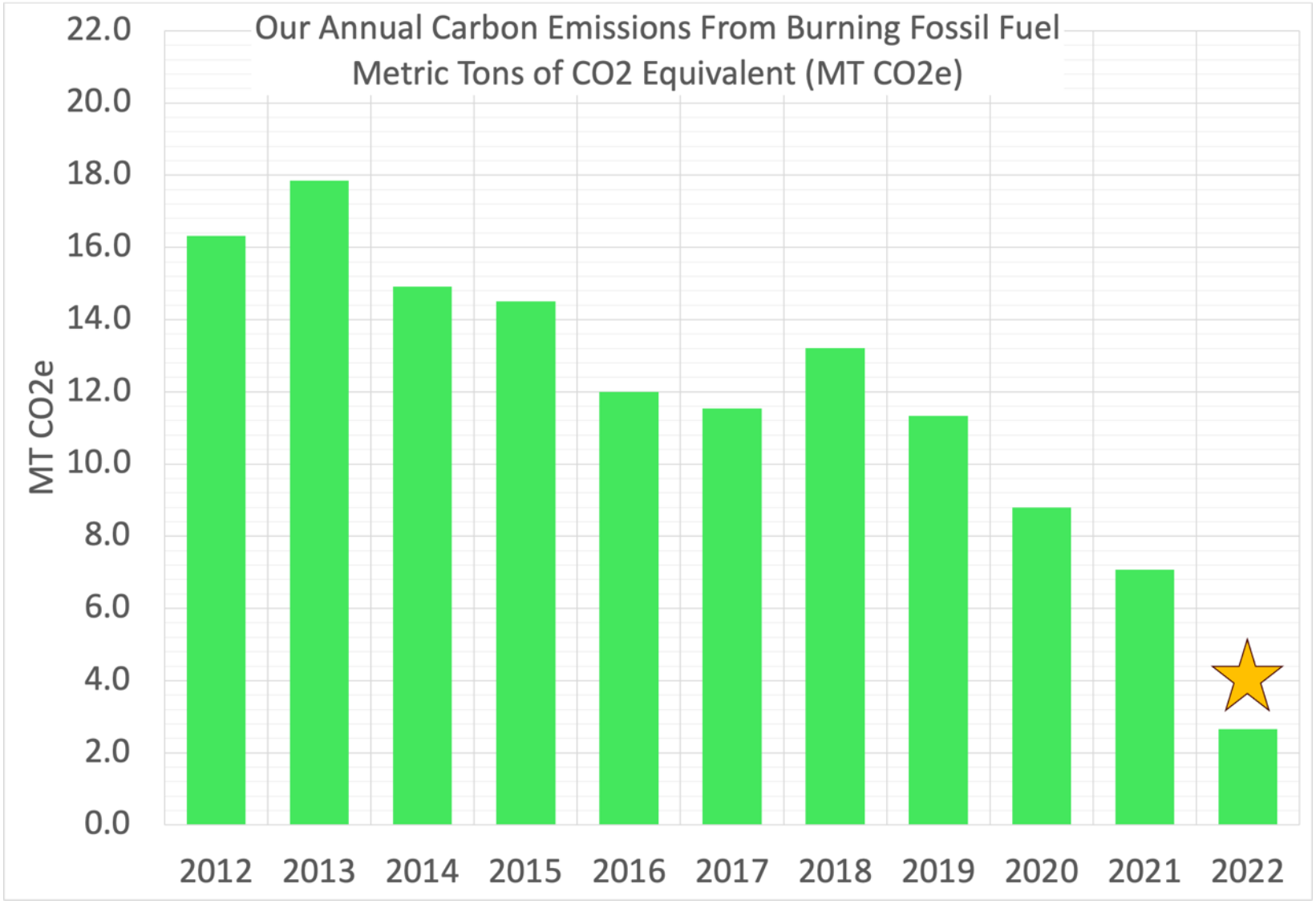
2023

WESTFORD CLIMATE ACTION

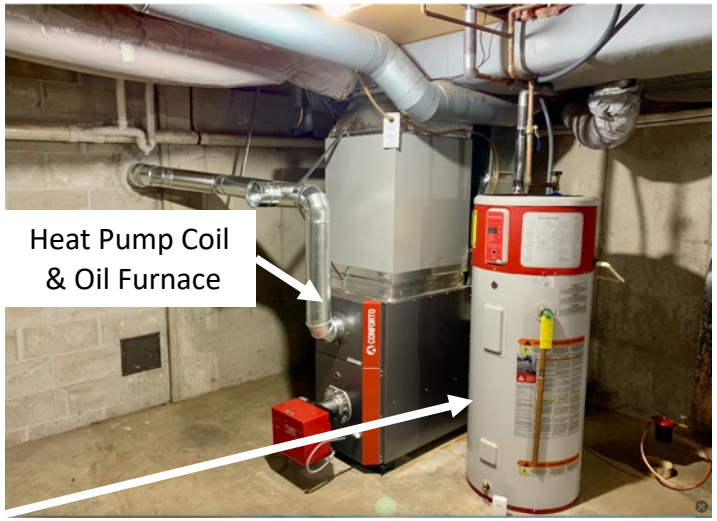
Our Goal Was to Reduce Our Carbon Footprint Over Time



- Motivated to Achieve a Net Zero Carbon Footprint
- Our Path was Tailored to Our Circumstances
- Took a Number of Steps Over 10 Years
- Leveraged Over $54K in Incentives
- Reduced our Home Energy Use by 64%
- Reduced our Carbon Footprint by 85%
- Our Annual Energy Costs Have Not Changed Substantially
- This Presentation Describes Our Journey→ Yours May be Different

Key Elements on Our Multi-Year Journey to a Near Net Zero Home

37 Panel, 9.4 kW Roof Top Solar Panels



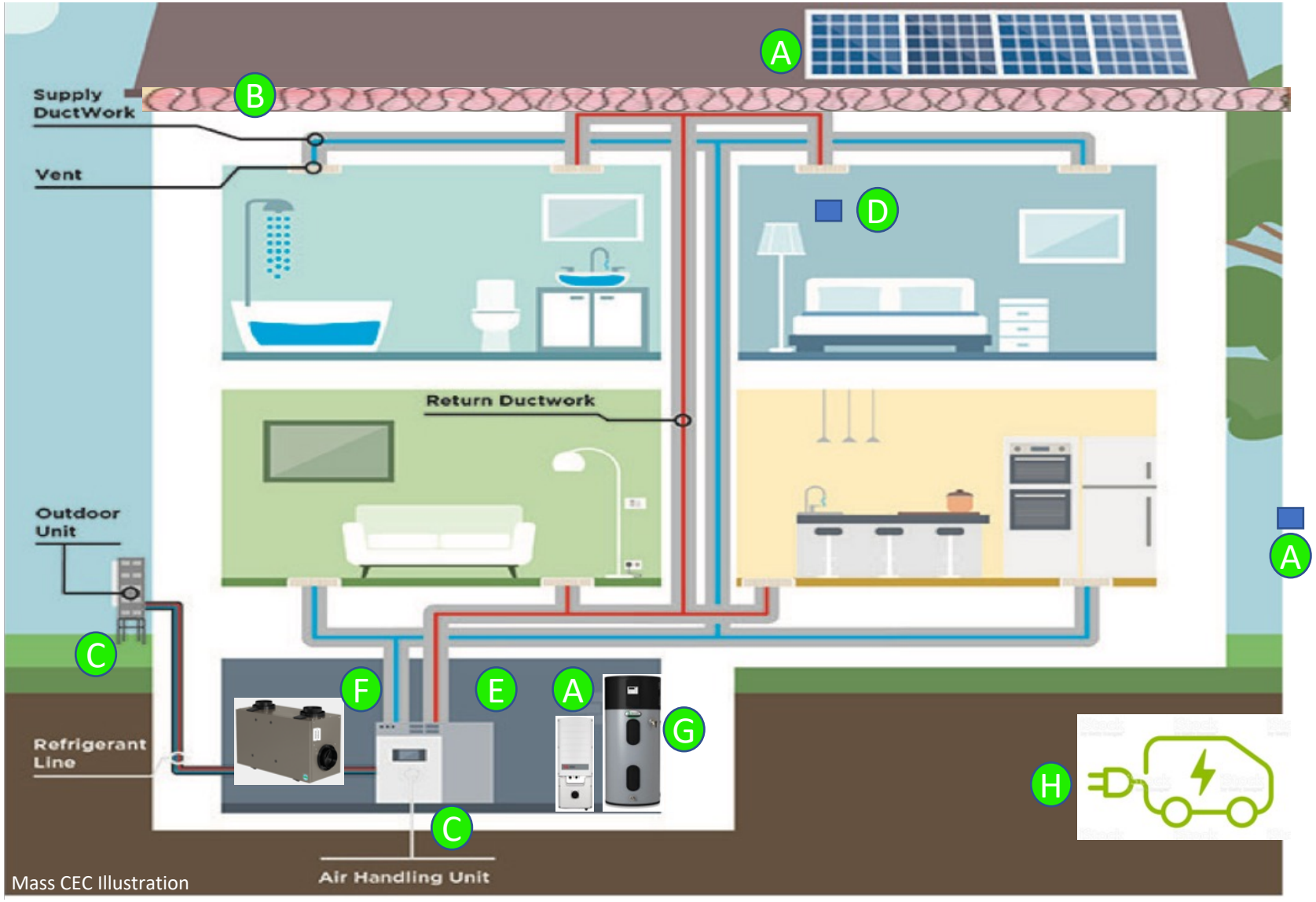
Air Source Heat Pump Water Heater

5-Ton Central Ducted Air Source Heat Pump

Toyota Prius Prime Plug-in EV/Hybrid

- Several Favorable Circumstances Helped
  - Near Ideal Solar Orientation/Shading
    - ✓ Relatively New Roof
    - ✓ Ideal for On-site Solar
  - Old Central Ducted Forced Air Oil Furnace with Whole House AC
    - ✓ Ideal for Conversion to Air Source Heat Pump System
  - Old Electric Hot Water Heater
    - ✓ Ideal for Conversion to Air Source Heat Pump Hot Water Heater
  - Old Car Needed Replacement
    - Ideal Timing to Purchase EV
- 8 Specific Actions Including
  - Purchased Roof-Top Solar
  - Installed ASHP Heating/Cooling System
  - Installed ASHP Hot Water Heater
  - Purchased Plug-in EV
- Reduced Our Annual Carbon Emissions to 2.7 MTCO2e

Diagram Illustrates the Range of Steps We Took



A. Roof Top Solar
- ✓ 37 Panels/20 Year Warranty
- ✓ 9.6 MWh Annual Production
- ✓ NGrid Net Meter
- ✓ Federal & State Incentives

B. Attic Insulation/Air Leak Sealing
- ✓ Added 16” Blown Attic Insulation
- ✓ MassSave Incentives

C. Central Ducted Air Source Heat Pump
- ✓ Bosch 5-Ton Heat Pump
- ✓ Auxiliary Oil Furnace
- ✓ MassSave Incentives

D. Smart Thermostat
- ✓ Programmable/On-line Monitoring
- ✓ MassSave Incentives

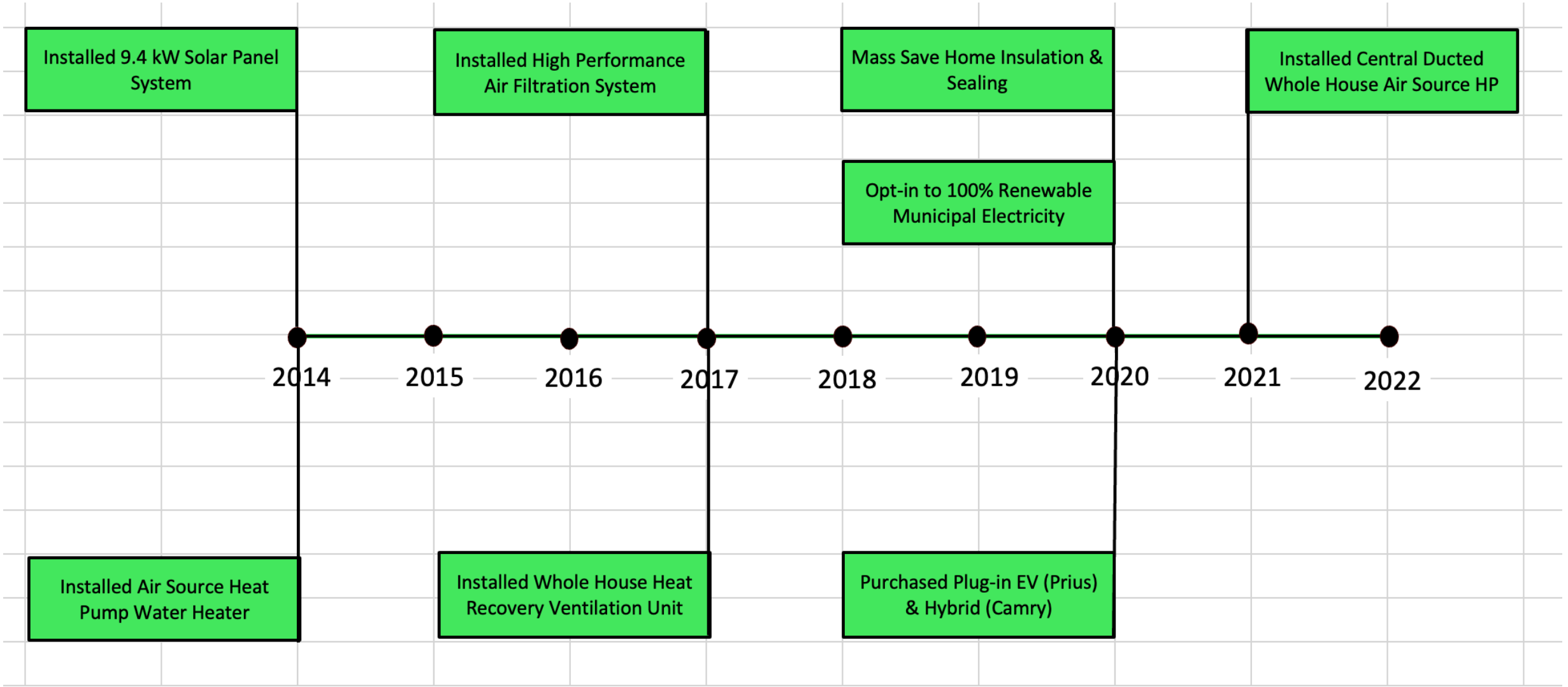
E. High Performance Air Filtration
- ✓ MERV16 Filter
- ✓ Anti-Germicidal UV Lamp

F. Heat Recovery Ventilation
- ✓ Whole House Ventilation
- ✓ 80% Heat Recovery

G. Air Source Heat Pump Water Heater
- ✓ 50 Gallon Capacity/3x More Efficient
- ✓ MassSave Incentives

H. Plug-in EV Hybrid Car-Level 1 Charging
- ✓ 110 VAC Standard Outlet
- ✓ Overnight Charge

You Don't Have to Do It All at Once or in This Sequence→But We All Need to Start Down the Path



Tip 1: Consider Mass Save Weatherization as an Easy 1st Step

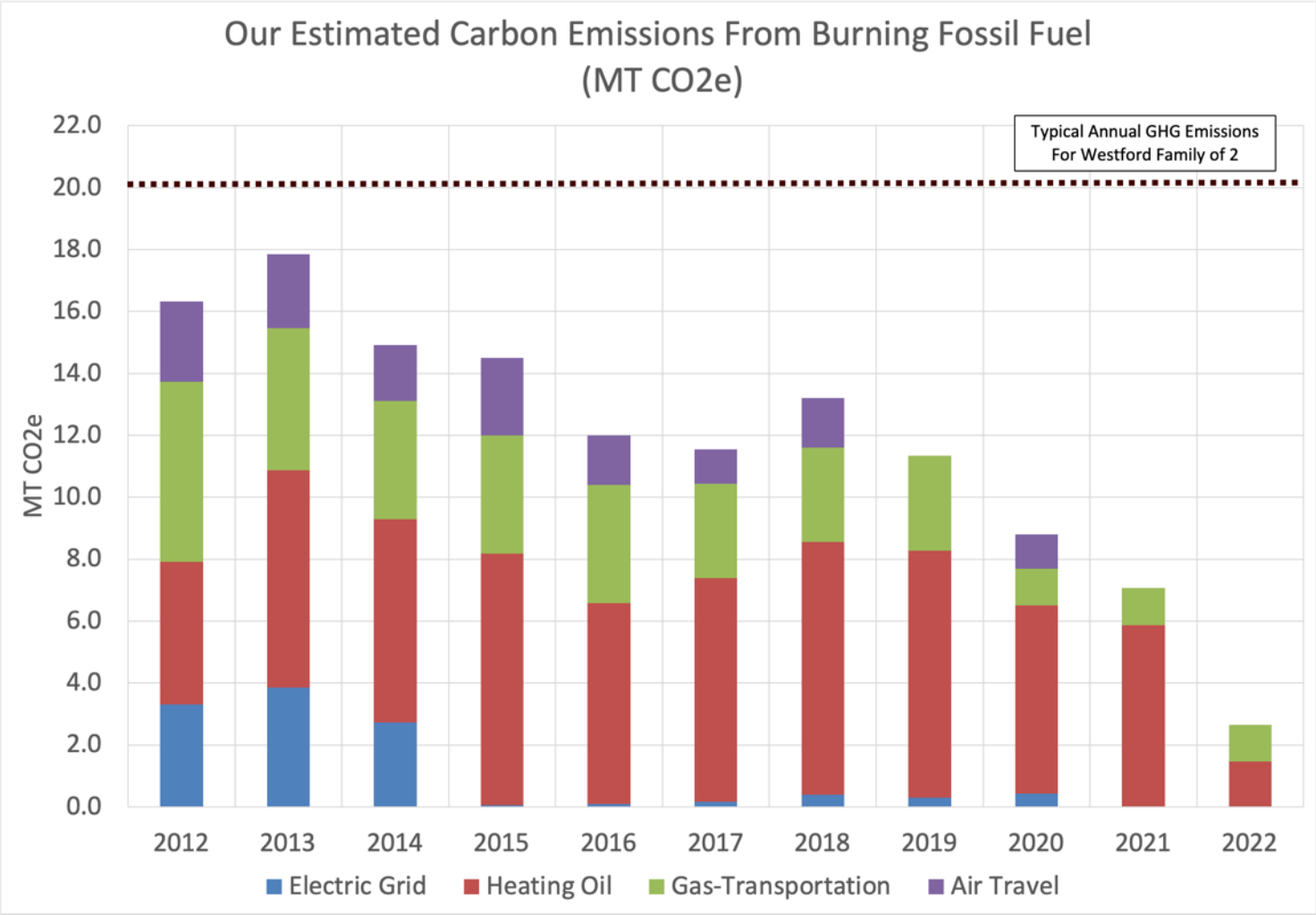
Tip 2: If Going Solar→ Account for Anticipated Future Changes in Electricity Consumption for HPs and EVs

Available Government Incentives in the 2014 -2021 Timeframe Covered 60% of the Acquisition Costs→ Current Incentives are Different

Yr	Item	Federal Incentive($)	State Incentive($)	Comment
2014	ASHP Hot Water Heater	$300	$750	Fed Tax Credit & MassSave
2014	Solar Panels	$10,390	$1,000	30% Federal Tax Credit
2014	Solar SREC II Program-10 Years	$0	$25,000	State SREC II Program
2017	High Performance Air Filtration	$0	$0	-
2017	Whole House Heat Recovery Ventilation			
2020	Prius Plug-in EV	$4,502	$1,500	Federal Tax Credit
2020	Home Sealing/Insulation	$0	$4,500	MassSave
2021	Central Ducted Whole House Air Source HP/Back-up Furnace	$200	$6,283	Fed Tax Credit & MassSave
Total		$15,392	$39,033	$54,425 Total Incentives

Additional Solar Panel Electricity Savings ~$45,000 Over 20 Years!

We Have Reduced Our Carbon Footprint by 85% → Now Near Net Zero



MT CO2e: Metric Tons CO_2 Equivalent (Includes CO_2, Methane, Nitrous Oxide, HFC's)

- 2013 Retired→ Reduced Car Mileage by 30%
- ★ 2014 Installed Air Source Heat Pump Water Heater→ Reduced Electric Bill by 25%
- ★ 2014 Installed 9.4 kWatt Solar Panel System→ Covered ~90% Electricity Needs
- ★ 2020 Mass Save Home Insulation & Sealing→ Reduced Oil Usage by 10%
- ★ 2020 Purchased Plug-in EV (Prius) & Hybrid Camry→ Combined ~150 MPG
- 2020 Opt-in to 100% Renewable Municipal Electricity Program
- ★ 2021 Installed Centrally Ducted Air Source Heat Pump→ Reduced Oil Usage by 74%
- Reduced Air Travel by Choice

★ Leveraged $54K in Incentives

The Jargon can be Confusing→ Installers, Coaches and On-line Resources Can Help

Mass Save

Integrated Controls

Ton

HSPF

SEER

Mini-Split

AHRI Capacity Ratio (17°/47°)

CoP

TSRF

MERV

Balance Point

Heat Load

Geo-Thermal

Ductless

SMART

ccASHP

SREC

Manual J

BTU/hr

HVAC

kWh

Net-Meter

Residential Solar – Biggest Single Step We Took

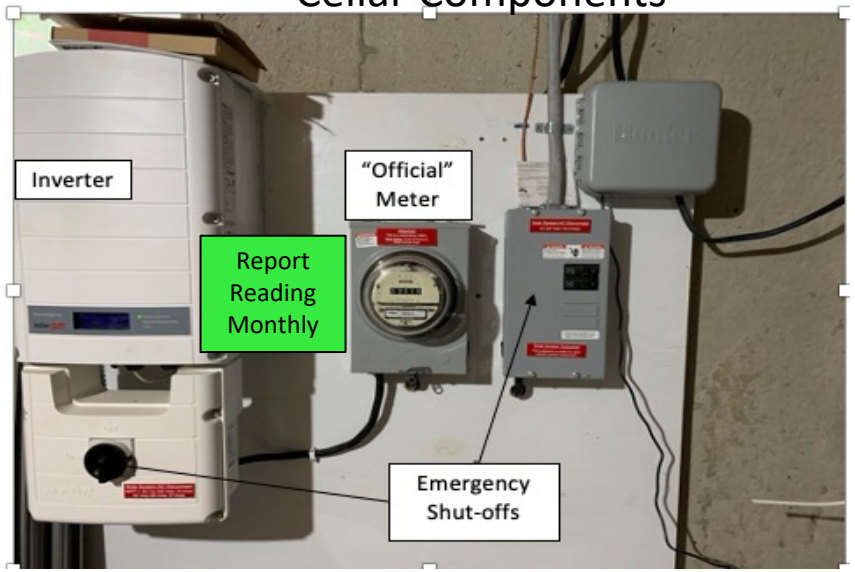
If Orientation/Shade/Pocket Book Permits→ Excellent Investment!

- Purchased Residential Solar in 2014
- Driver was Carbon Footprint Reduction
- Federal/State Incentives Made it Economically Attractive
- Enrolled in State's SREC II Program
  - ✓ Solar Renewable Energy Credits
  - ✓ Added Financial Incentive for "Green" Electricity Production
- Investment Break-Even was Less Than 6 Years
- Financial Benefit Over 20-Years
  - ✓ SREC Income(10 Years): ~$25,000
  - ✓ Electricity Savings(20 Years): ~$45,000
- CO_2 Savings(20 Years): ~300,000 lbs

There Are a Number of Components to Residential Solar

Roof Top Panels

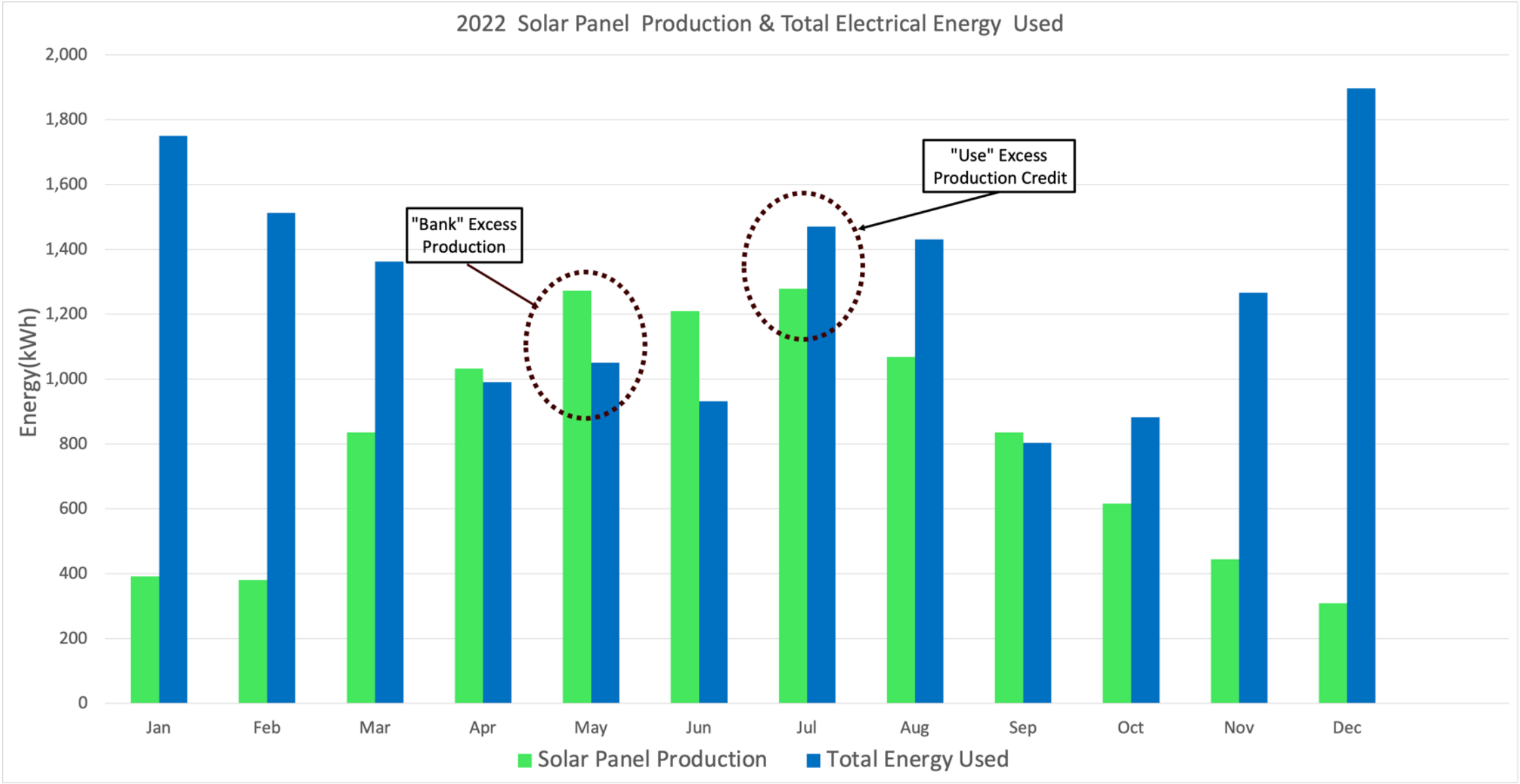
Cellar Components



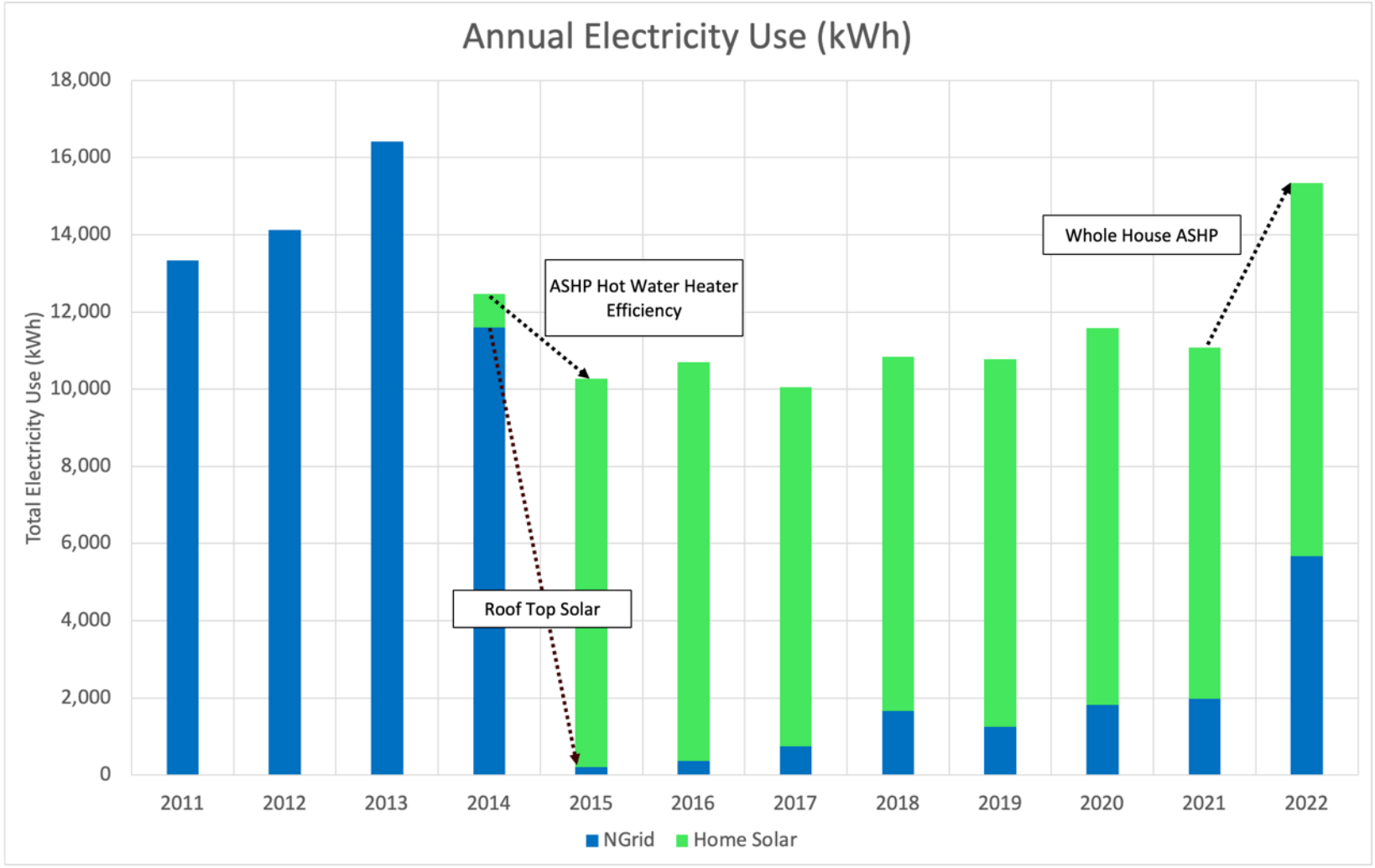
Roof Re-Inforcement (if Necessary)

External Components

Solar Panel Production Varies Greatly Over the Year Net-Metering Allows You to Bank Excess for Later Use



Annual Electricity Use Highlights the Benefits of Home Solar & Impact of Heat Pumps

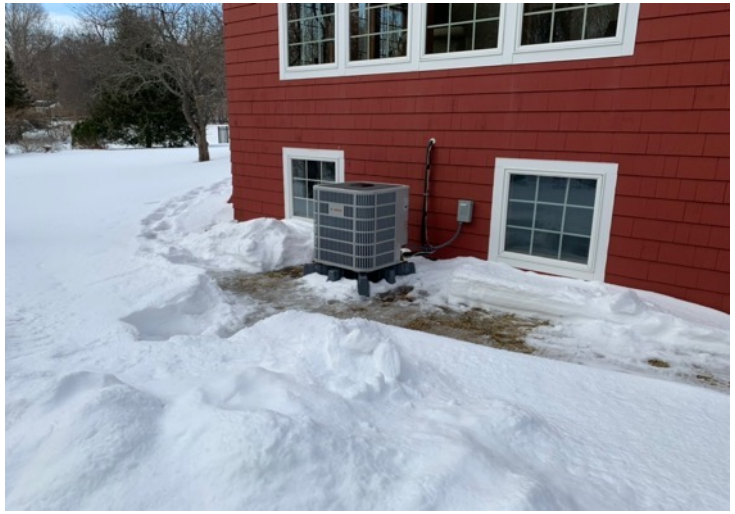


A Cold Climate ASHP is Now an Affordable Eco-Friendly Way to Heat and Cool Your Home

- Where We Started (2021)/Every Situation is Different
  - Central Ducted Oil Furnace/Conventional AC
  - 20 Year Old System Reaching End of Useful Life
  - ASHP Hot Water Heater→ Cut Electric Bill by 25%
  - Use ~700 Gal of Oil per Year→ ~7 Tons of CO_2/Year
  - Have Solar Panels→ Use ~1,500 kWh from Grid/Year
- Motivated to Reduce Carbon Footprint
- Considered Multiple Heating & Cooling Options
  1. All Electric Central Air Source Heat Pump (ASHP)
  2. Hybrid ASHP with Back-up Oil Furnace
  3. All Electric Geo-Thermal Heat Pump (No-High Cost)
  4. Conventional AC/Oil Furnace (No-High Carbon Footprint)
- Selected Option 2: Hybrid (Dual Fuel) System
  - Bosch 5-Ton Cold Climate Air Source Heat Pump
  - Granby High Efficiency Oil Furnace/Air Handler (Back-up)
  - Eco-Bee Smart Thermostat
  - ~$10K After Rebates/Incentives→ Cost Competitive Solution
- Results are in: Reduced Oil Use by 74%/Reduced Carbon Footprint by 4.5 Metric Tons/yr

Some Selected Views of Heat Pump Equipment

5-Ton Central Ducted Air Source Heat Pump



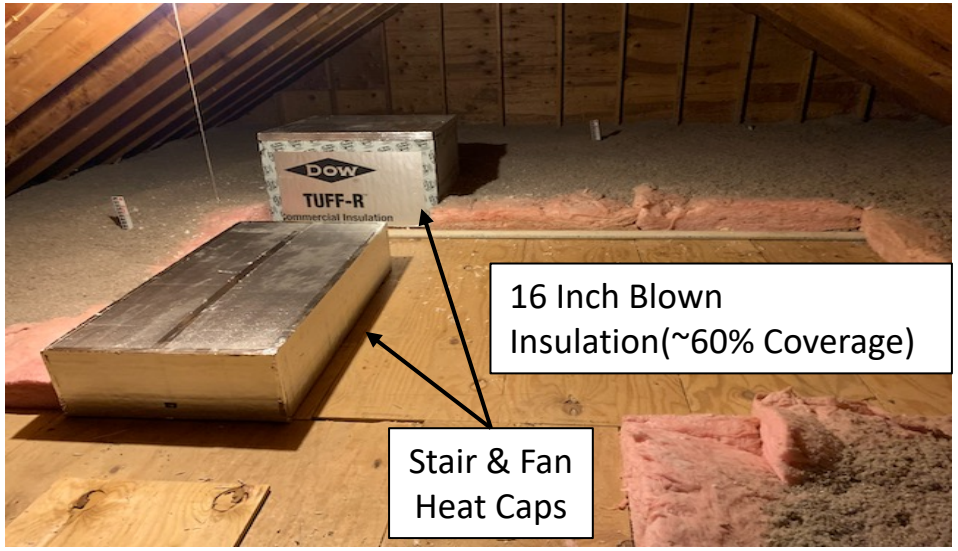
Helps to Clear Snow in Winter For Efficient Operation

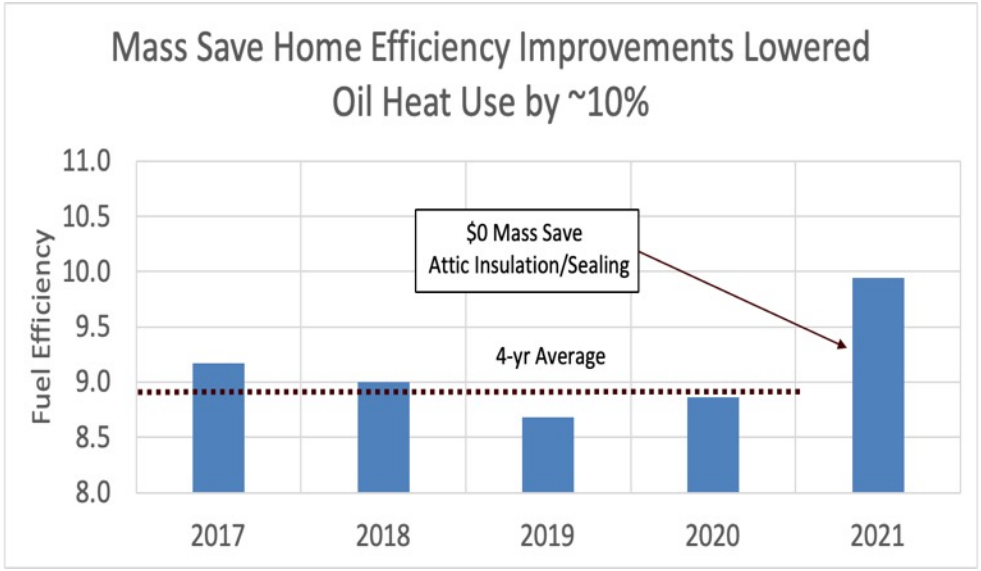
Heat Pump Moisture Plume – In Automatic Defrost Mode

Heat Pump Coil & Fan/Back-up Oil Furnace/Air Filter Stack

Air Source Heat Pump 50-Gallon Water Heater

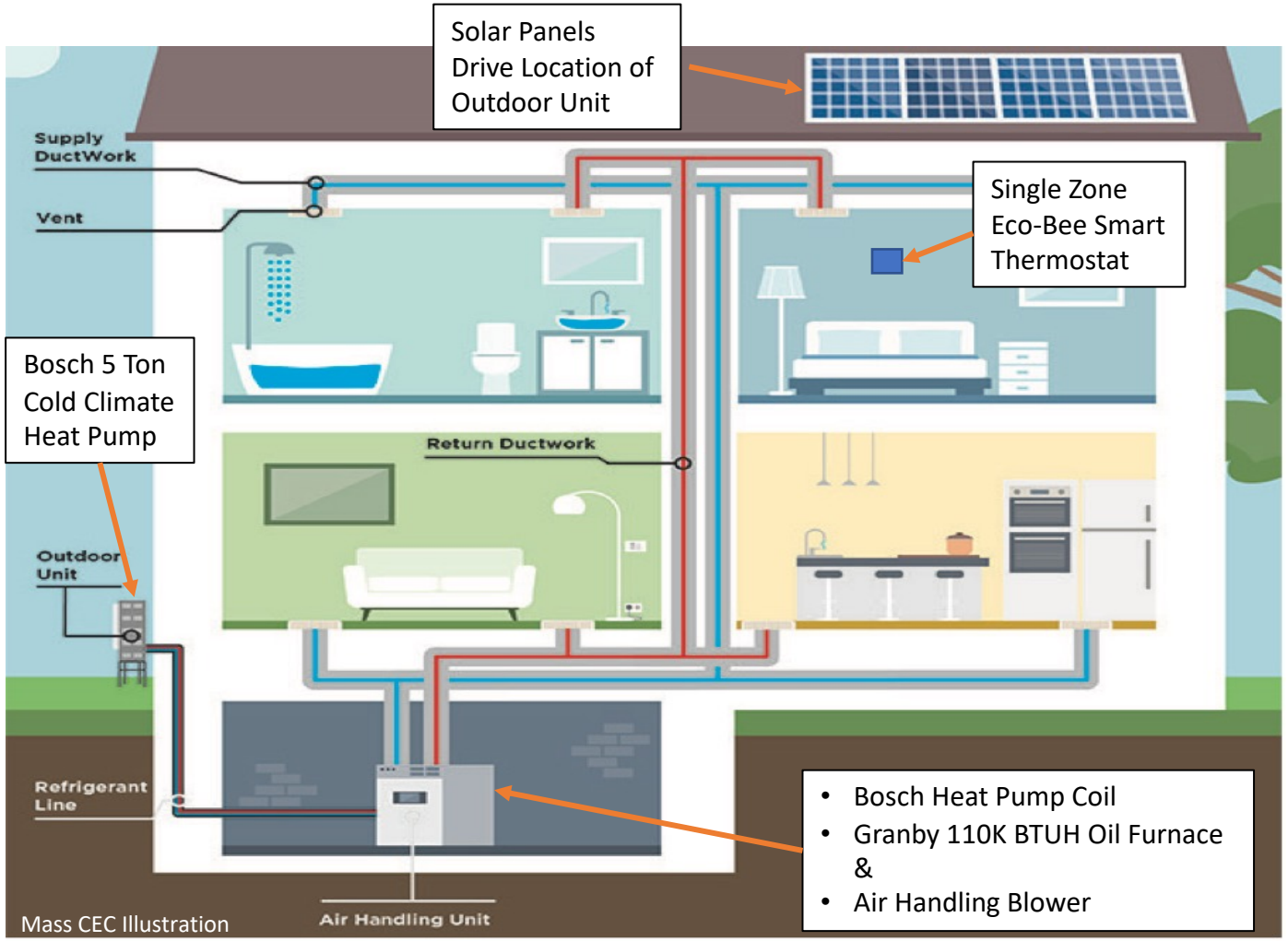
Key Step: Mass Save Energy Audit and Insulation & Sealing Upgrades





- Conducted Mass Save Energy Audit as a Necessary 1st Step to Heat Pump Conversion
- Provided Increased Attic Insulation and Sealing of Air Leaks
  - 16 Inch Blown Insulation in Attic Space
  - Improved Heat Caps
  - Improved Door Seals
  - Reduced Air Loss by 25%
- Saw Year Over Year Improvement in Oil "Fuel Efficiency" of ~10%
  - Measured in Degree Days/Gallon
- Contractor Services Provided at $0 Cost Due to Pandemic Restart
  - $4,500 Value
  - Typically 75% Subsidy

Central Air Source Heat Pump With Back-up Furnace Uses Existing Ducts and has Indoor and Outdoor Units



Dual Fuel Systems Can Use Either Electric, Oil or Gas Back-up

- Why a Hybrid(Dual Fuel) System?
  - Balance Cost, Performance & Efficiency
  - Can Run Furnace on Back-up Gasoline Generator (When Needed)
  - No Anxiety at Extreme Low Temperature
- Outdoor Unit
  - Bosch "5-Ton", 16 SEER, 10.5 EER, 9.5 HSHP
  - Cold Climate Certified, On Mass Save List
- Indoor Unit
  - Bosch Indoor Unit-Heat Transfer Coils
  - Granby 110 K BTUH Oil Fired Furnace
  - Granby Variable Speed Air Handling Unit
  - All Components on Mass Save List
- Thermostat
  - Eco-Bee Smart Thermostat
  - Programmable Switchover Temp→ HP to Furnace→ We Set at 20°F
- Solar Panels
  - Snow Drop From Solar Panels Restricts Location of Outdoor Unit

Ducted Air Source Heat Pumps Have Very Similar Physical Footprints to Conventional Heating and AC Units

Outdoor Heat Pump Condensing Unit

- Bosch 5 Ton Heat Pump-56 kBTU/hr
- 29 x 29 x 33 Inch High
- Keep Clean/Snow Free for Maximum Efficiency

Indoor Heat Pump Coil Unit

- Granby ”Low Boy” 110 kBTU/hr Oil Furnace-Non Condensing
- Bosch Indoor Coil Unit
- Granby ECM Variable Speed Air Handler

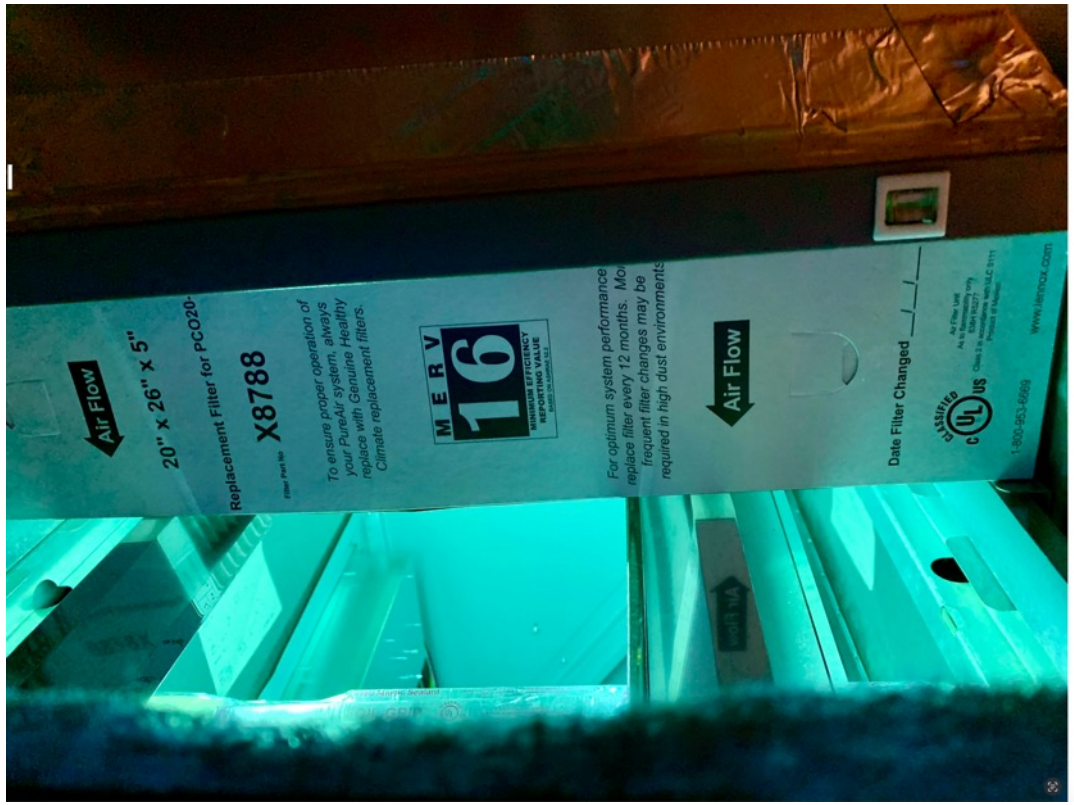
Oil Furnace With Variable Speed Blower

Ecobee Thermostat

- Smart Thermostat
- On-line Monitoring/Controls
- Single Zone
- Controls Both Heat Pump & Back-up Oil Furnace
- Switchover Temp Set at 20°F

Our Indoor Air Quality was Improved with High Efficiency Air Filtration & a Separate Whole House Heat Recovery Ventilation(HRV) Unit

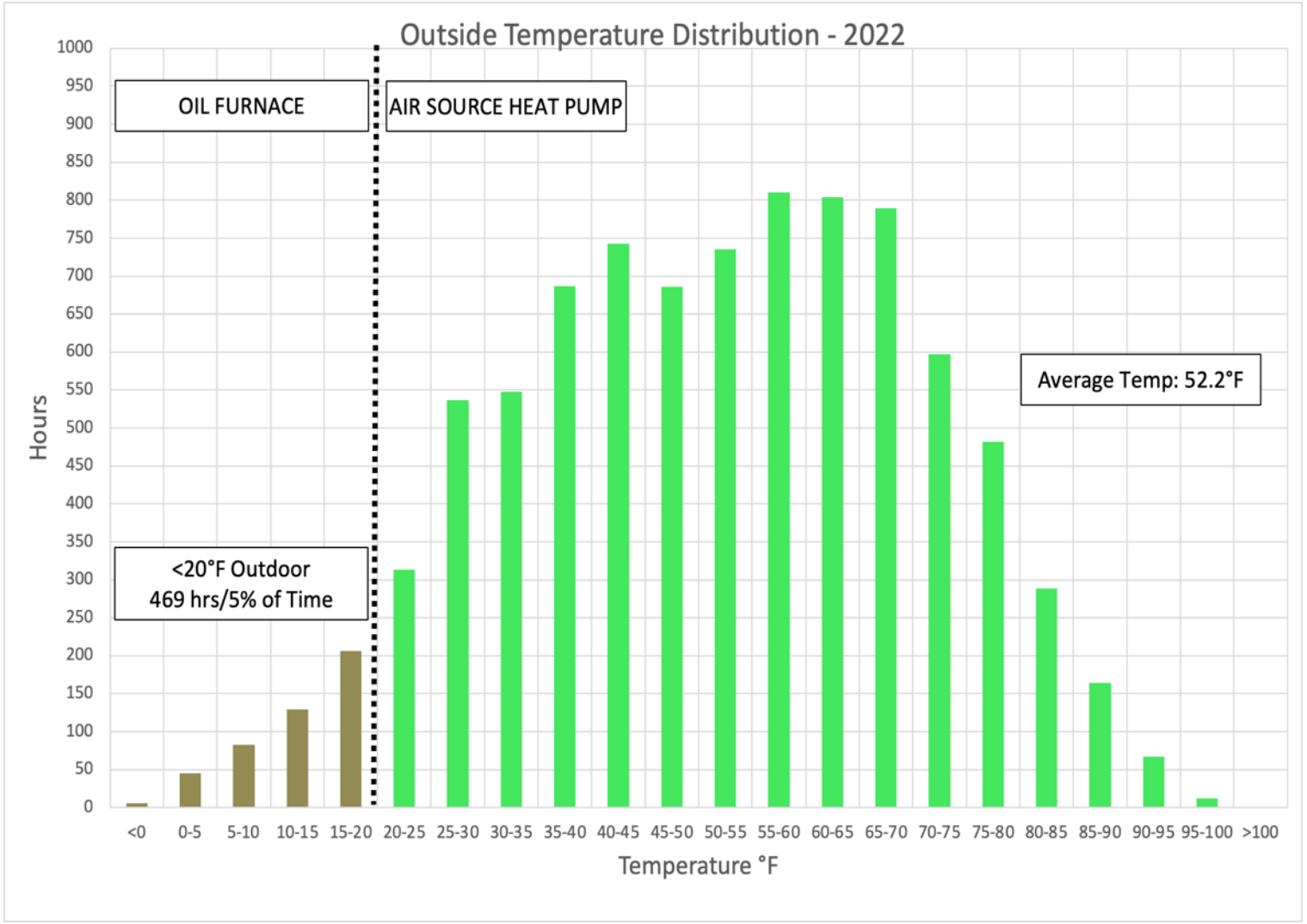
As You Better Insulate & Tighten Your Home Envelope, Indoor Air Quality May Become an Issue



Lennox High Performance(MERV 16) Air Filter With Anti-Germicidal UV Lamp is Part of our HVAC System

Separate Lennox Heat Recovery Ventilation Unit Brings in Outside Air With Minimal Heat Loss

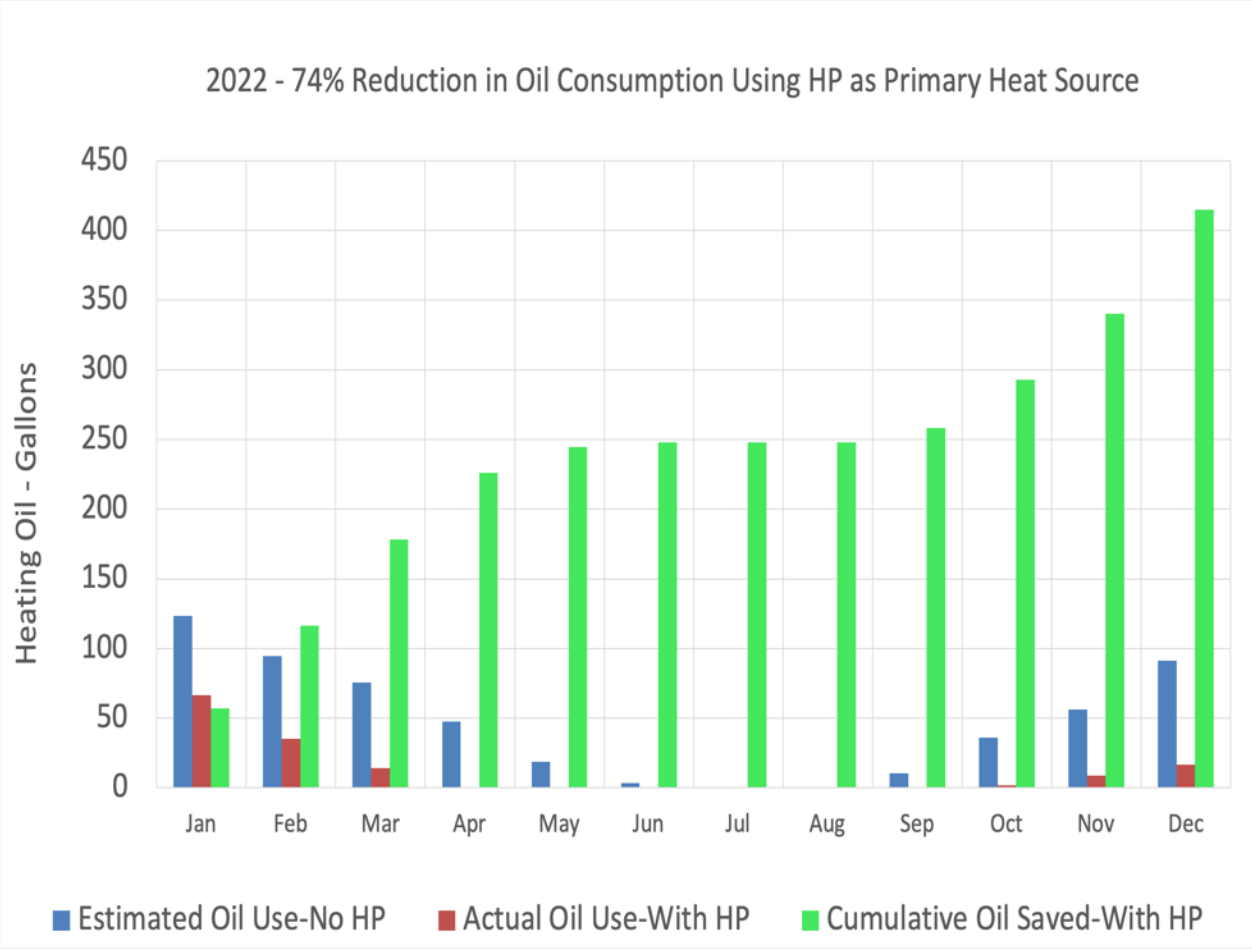
Smart Thermostat Monitors System Operation Including Indoor/Outdoor Temperature



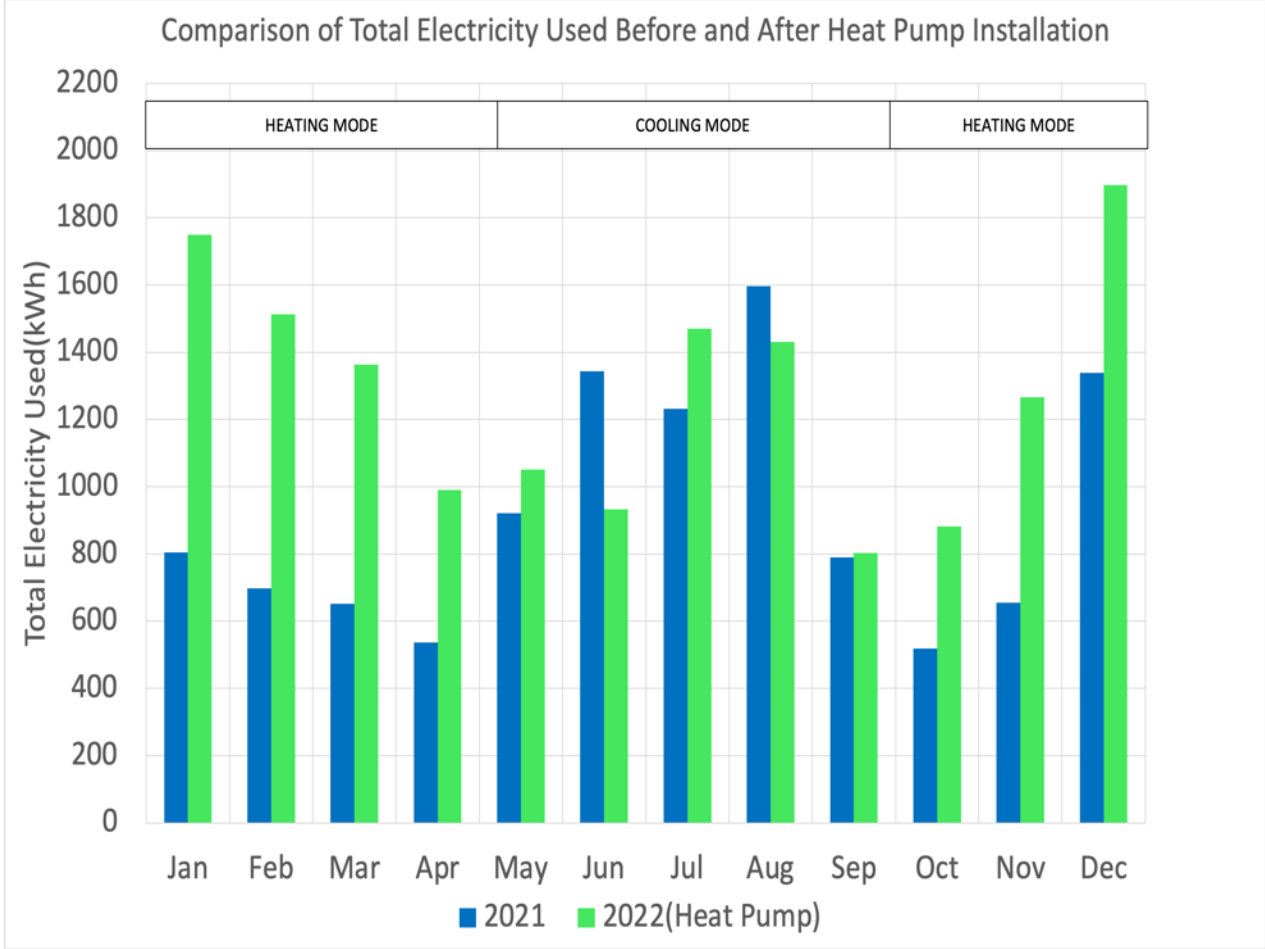
- Climate Statistics
  - Average Temp: 52.2°F
  - Nights Below 20°F: 34
  - Days Above 90°F: 27
  - Heating Degree Days: 5,578
  - Cooling Degree Days: 893
- Heat Pump Statistics
  - Days in Heating Mode: 216
  - Days in Cooling Mode: 69
  - Added Electricity Use: 4,126 kWh
  - 38% Increase in Annual Electricity Use
- Auxiliary Oil Furnace Statistics
  - On Below 20°F: 168 hrs
  - Oil Used: 143 gal
  - Oil Saved: 415 gal
  - 74% Oil Reduction

Use of Air Source Heat Pump Resulted in Significant Reduction in Oil Use But Increase in Electrical Use→ Notably in Heating Mode

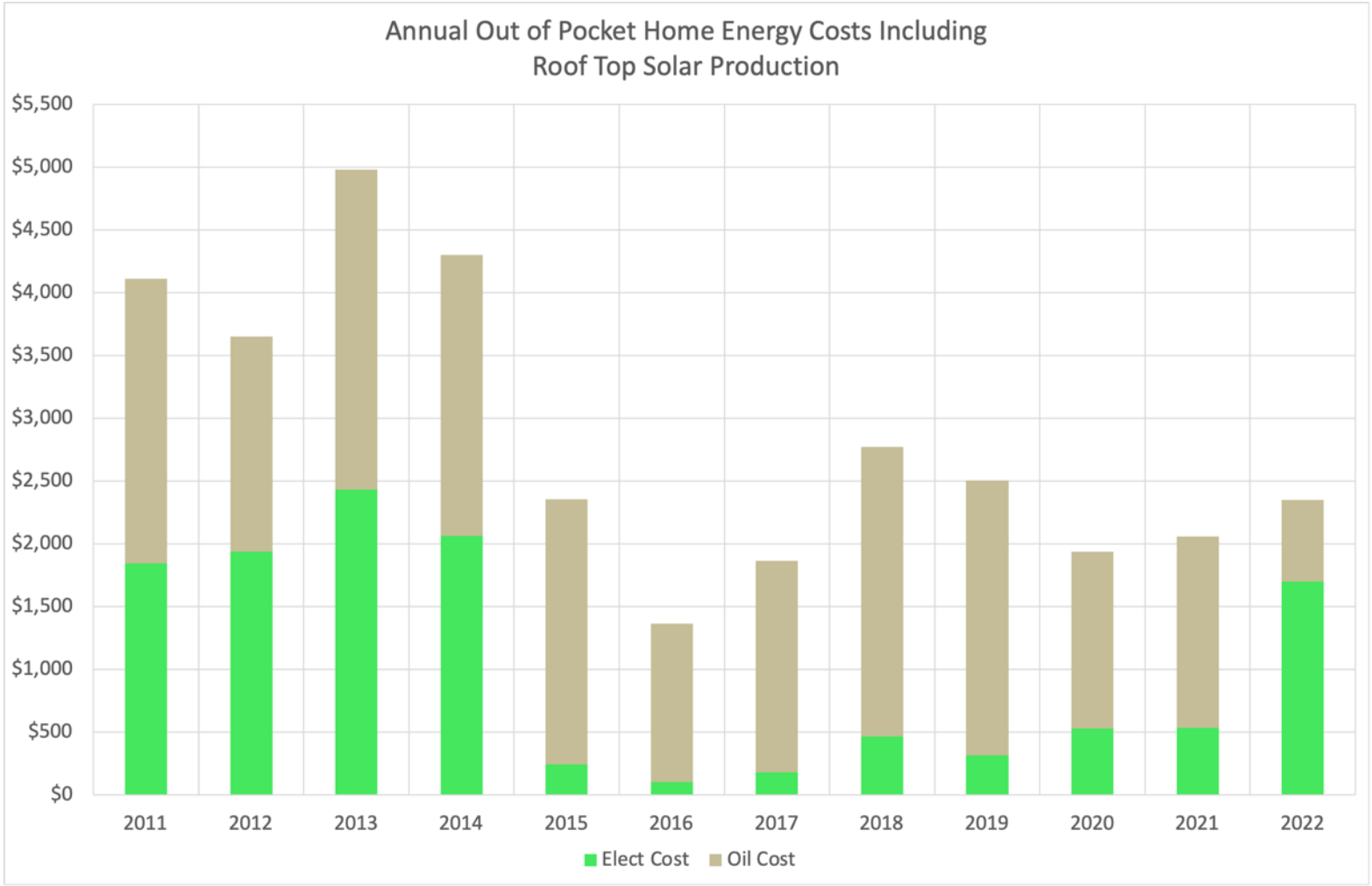
Reduction in Oil Use



Increase in Electricity Use



Annual Operating Costs for Hybrid (Dual Fuel) System is Comparable to Oil Furnace Only--> Oil Costs Decreased/Electricity Costs Increased as Expected



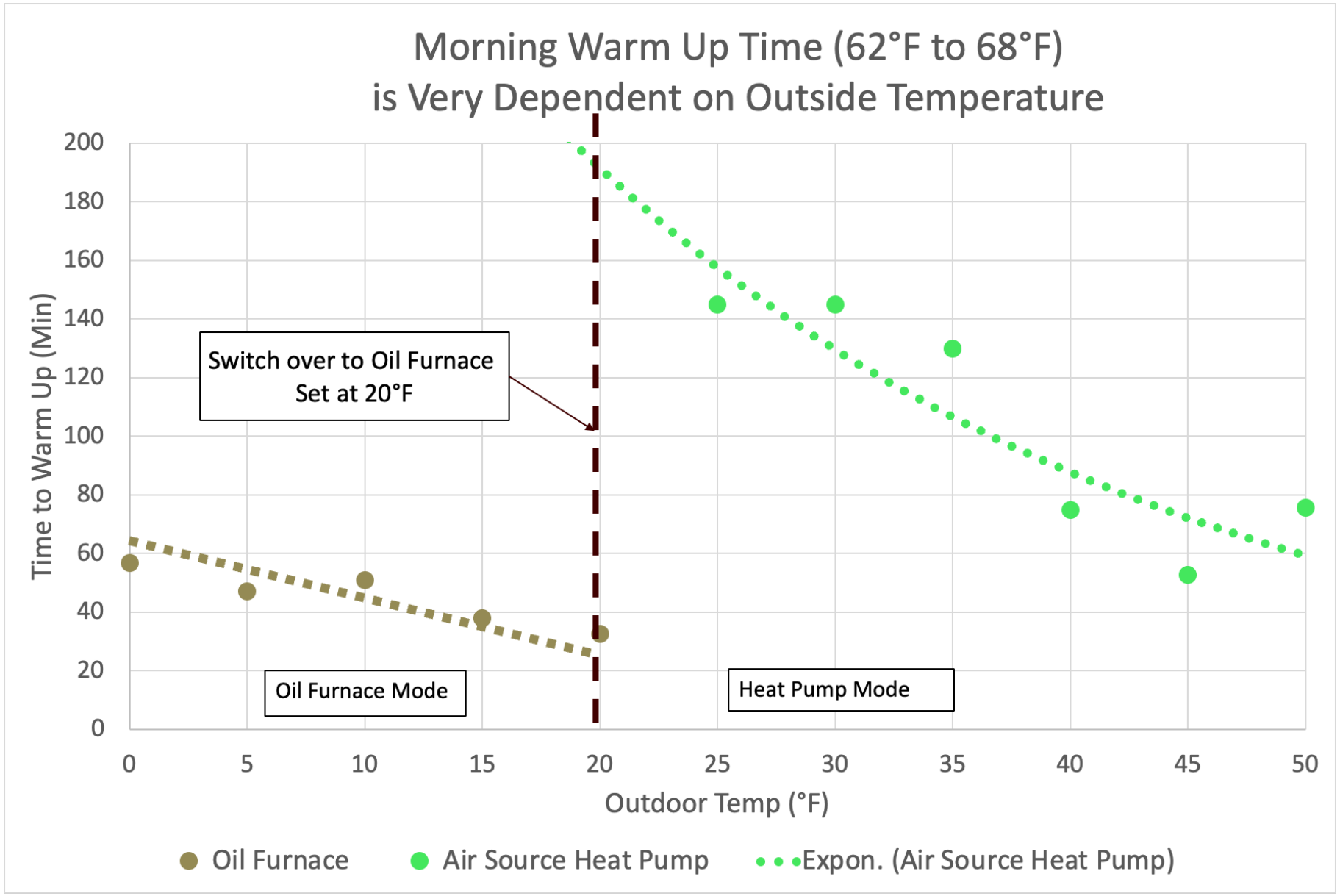
Operating Cost was Comparable <u>But</u> Carbon Footprint Significantly Reduced by 4.5 MTCO2e/Yr!

- 2022 Includes a Full Year With ASHP with Oil Furnace Back-up
- Oil Use Decreased by 74%
  - But Oil Price Increased 40% From 2021 to 2022
- Total Electricity Use Increased by 38%
  - Total Electricity Use: 15,348 kWh
  - Grid Electricity Use: 5,671 kWh
  - Elect Cost is High Due to
    - ✓ Participating in Westford POP Gold 100% Green Program
    - ✓ Gold Rate: $0.276/kWh
    - ✓ Higher Cost/Low Carbon Decision
  - Could Save ~$200 by Switching to POP Green
- Solar Electricity Production was Similar to Prior Years
  - ~9.6 MWh On-site Production

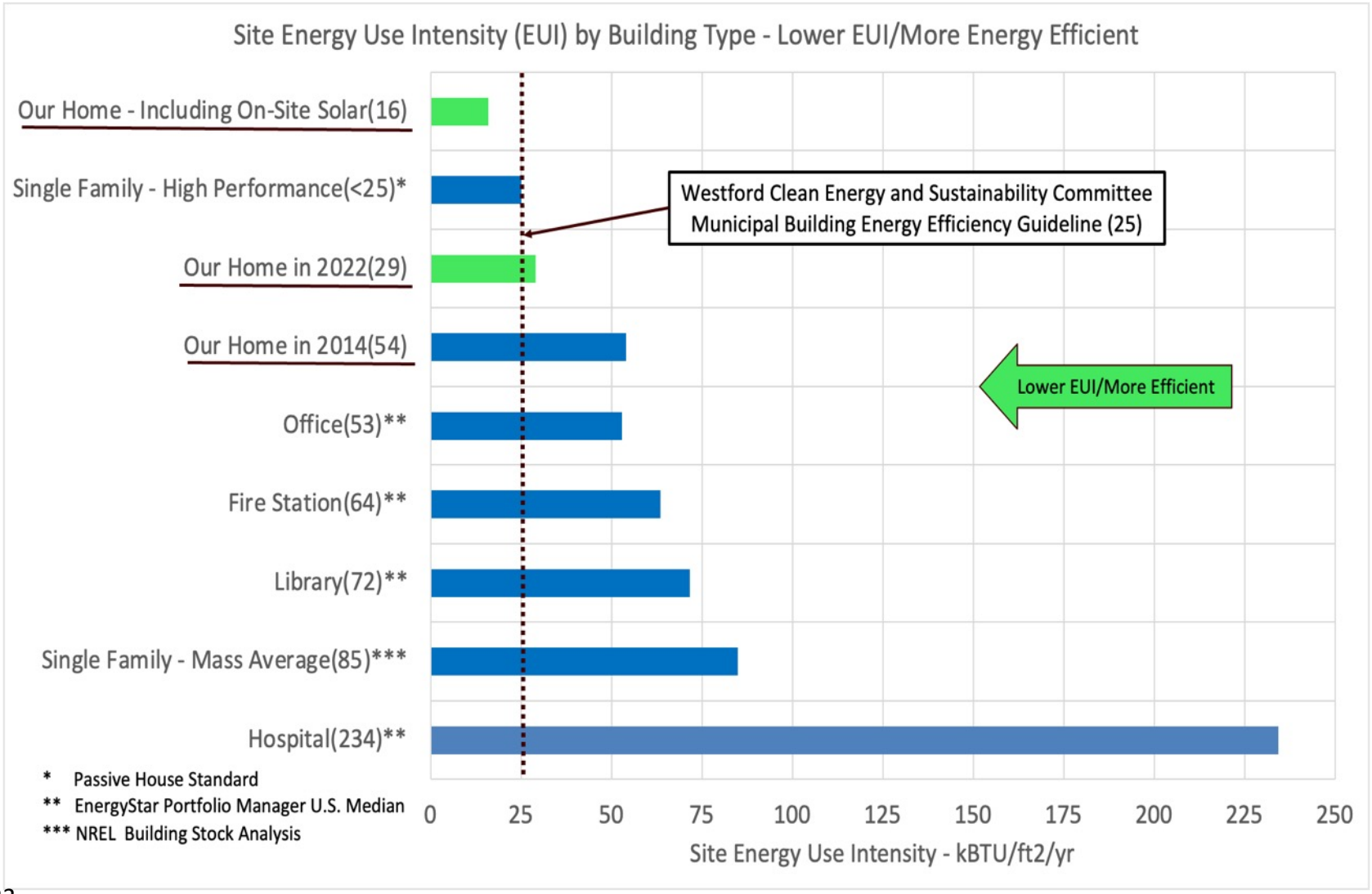
A Typical 24 Hour Cold Winter Day Heating Cycle Using Both ASHP(>20°F) and Auxiliary Oil Furnace(<20°F)→ Data Collected by On-Line Smart Thermostat

- Hybrid Dual Fuel System Keeps House Comfortable at Extremes
- Maintains Indoor Temperature Within 2°F of Desired Temperature
- Thermostat Set by User: 68°F Day/62°F Night
- Heating System Switchover Temp Set by User at 20°F
- Below 20°F Switches to Auxiliary Heat(Oil Furnace)
  - ASHP Lose ~30% Efficiency at 20°F & ~50% at 5°F
  - ASHP Takes Longer to Warm up House at Cold Outdoor Temperatures
- Ecobee Smart Thermostat
  - Remote Programmability
  - Constant Monitoring
  - Movable Room Sensors Provide Comfort Where You Are

One Disadvantage of a HP→ It Takes Longer to Warm Up Home at Lower Outdoor Temperatures

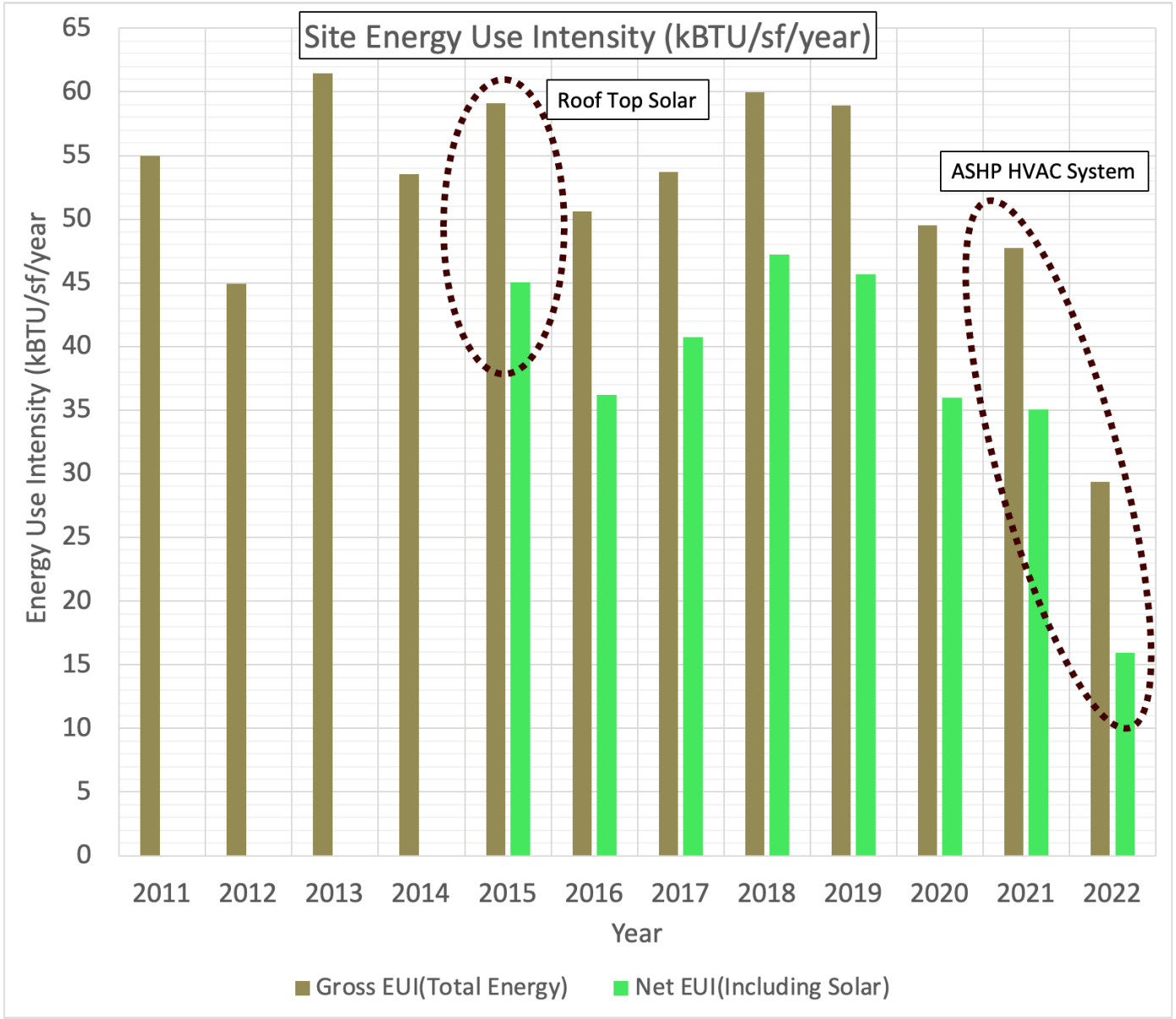


So How Well Did We Do in Reducing Our Energy Needs? Tracking Energy Use Intensity (EUI) is a Common and Very Useful Way to Assess Building Energy Efficiency



- Your Site EUI is Simply Your Total Annual Energy Use Divided by Your Total Living Area
- Need to Convert All Energy Units to kBTU's
  - EUI Units--> kBTU/ft2/yr
- Allows Energy Efficiency Comparisons to Other Buildings
- EUI Varies by Building Function
- Mass Detached Single Family Average EUI is 85***
  - Newer Homes(>1980) ~50
  - High Performance Std is <25
- Home Analysis
  - With Efficiency Improvements
  - Gross EUI is 29
  - Including On-Site Solar, Net EUI is 16
- CEASC Municipal Building Guideline is Site EUI <25

Tracking Annual Site Energy Use Intensity(EUI) Provides Homeowner Insight Into Benefits of Specific Home Energy Efficiency Improvements



- Track Total Energy Use and On-site Solar Offset (Net EUI)
- How Much Energy Did You Use?
  - ✓ Independent of Cost
  - ✓ Include All Sources
  - ✓ Universal Industry Metric
- Allows Comparisons
  - ✓ Year Over Year
  - ✓ Similar Homes
  - ✓ Industry Benchmarks
- Benefit of Major Actions are Clear
  - ✓ On-Site Solar
  - ✓ Whole House Air Source Heat Pump HVAC System

2020 Prius Prime EV Plug-in Hybrid Gets ~25 Miles per Charge/~260 MPG With a Mix of Electric and Hybrid Modes of Operation→ Well Matched to Our Needs

2020 Toyota Prius Prime is a Plug-in EV/Hybrid

Exceptional MPG With No Range Anxiety

120v Level 1 Charger in Garage Provides Overnight(5.5hr) Charging - 9.6 kWh Battery Capacity

Where to Start? Some Thoughts Based on Our Experience

- Baseline Your Own Situation
  - Calculate Your Current Carbon Footprint
  - Calculate Your Current Home Energy Efficiency (EUI)
  - Check on Windows/Appliances/HVAC Age→ Develop Replacement Plan
  - Expect Your Journey to Take Multiple Years→ Ours Took ~9 Years
- Learn About Available Incentives→ Do Your Research!
  - Get MassSave Home Energy Audit→ it's Free
  - Federal & State Incentives are Significant
- Check to See if On-site Solar Works for You→ Likely Single Biggest Payoff
- Improve Your Home Energy Efficiency (EUI)
  - Better Insulation & Air Sealing Using MassSave
  - With Better Sealing Consider Your Indoor Air Quality/Ventilation
- Electrify Everything You Can as Efficiently as Practicable
  - Air Source Heat Pump Domestic Water Heater
  - Air Source Heat Pump for Space Heating & Cooling
- Consider Stepping up to a Higher Green Electricity Content Through Westford's Municipal Aggregation Program→ It's Cheaper Than NGrid

Learn More at

WESTFORD CLIMATE ACTION

Westfordclimateaction.org

Westford Massachusetts

westfordma.gov/Sustainability

Appendix

Key Parameters and Conversion Factors Used to Determine Carbon Emissions & EUI

CO2 Emission Factors

Type	CO2 Emission Rate	Units	Source	Last Release	Note
Electricity	480.18	lbs/MWh	EPA eGrid NPCC New England https://www.epa.gov/egrid/power-profiler#/NEWE	Jan 2022	National Average is 818 lbs/MWh; NE Emission is 528 lbs/MWh reduced by 10% for Westford POP Default rate
	2.35E-04	MT/kWh			
Gasoline	8.89E-03	MT/Gallon	EPA https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references	Jun 2022	EPA Greenhouse Gases Equivalencies Calculator
Heating Oil	10.19	kg/Gallon			
	1.02E-02	MT/Gallon			
Natural Gas	0.0053	MT/Therm			
	0.0551	MT/Mcf			
Forest Sequestration	-0.84	MT/acre/yr			
Air Travel	Trip Dependent		International Air Tansport Association(IATA) CO2 Connect Calculator		

Conversion Factors

Electricity	3.412	kBtu/kWh	US Energy Information Agency https://www.eia.gov/energyexplained/units-and-calculators/	Jun-22	eia: Units and Conversions Explained
Gasoline	120.238	kBtu/Gallon			
Heating Oil	137.381	kBtu/Gallon			
Natural Gas	1,037	Btu/cf			
Natural Gas	0.01037	Therm/cf			