

Cost of Avoided Carbon Model

Initial Findings

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December 7, 2019

VECAN Conference



About the Department of Public Service

The Department of Public Service (PSD), housed within the executive branch of Vermont state government, is charged with representing the public interest in energy, telecommunications, water and wastewater utility matters.

By law, state energy planning should:

- Assure Vermont's needs are met with resources that are least cost, reliable, secure, and sustainable
- Assure affordability
- Encourage economic vitality

(30 V.S.A. § 202a)

Vermont's Carbon Reduction Goals

Goals in 2006 Statute

- ↓ 50% by 2028
- ↓ 75% by 2050

Baseline Year: 1990

Source: 10 V.S.A. § 578

Goals in 2016 Comprehensive Energy Plan

- ↓ 40% by 2030
- ↓ 85% to 95% by 2050

Baseline Year: 1990

Source: 2016 Plan, p. 4

Other Goals in Statute: Renewable energy, weatherization

Sector-Specific Targets in Energy Plan: Transportation, electricity, building heating, state agencies, etc.

Select Carbon Reduction Policies

- Energy efficiency utilities
- Low income weatherization
- Renewable Energy Standard
 - Tier I: Total Renewable Energy
 - Tier II: Distributed Generation
 - Tier III: Energy Transformation (fossil fuel / GHG reductions)
- Public transportation
- Park and ride support
- Complete streets policy
- State Energy Management Program
- State EV Incentive Program
- State BGS fleet EV target
- Clean Energy Development Fund
- Wood Energy Program
- VW Settlement Funding
- Act 250 Criterion 9(L) related to settlement patterns

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Objectives & Methodology

Objective

Given the need for carbon reduction, compare measures across different sectors using available data

- Estimate carbon reduction per dollar invested
- Inform a portfolio approach (not exhaustive, not the sole measure of value)

General Methodology

- Calculate carbon reduction associated with measure over lifetime
- Calculate readily quantifiable benefits and costs
 - Directly attributable economic costs and benefits accruing to Vermonters (externalities excluded given inconsistent/unavailable data)
 - Flexible using selectable options for incentive amount, equipment size, etc.
- Result: Compare carbon reduction net cost using net present value

Caveats

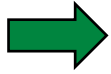
- The model is still in draft form and subject to revision
- Limited to select carbon reduction measures
 - Carbon reduction is not always the primary objective for each measure
- Variety of assumptions for each measure
 - Future costs may decrease (EV) or performance may improve (heat pumps)
- Some societal benefits are excluded, such as comfort and health
- Estimates are a snapshot in time; based on 2018 data
 - Increasingly renewable grid is included
 - Distribution system upgrade costs are not included
- Estimates are representative of measures, but do not reflect range of measures

Measures Included

- Electric Vehicles
 - All-Electric Vehicles
 - Plug-in Hybrid Electric Vehicles
 - Electric School Buses
 - Electric Transit Buses
- Energy Efficiency Measures
 - On a per-measure basis
 - Efficiency Vermont Portfolio average
- Cold-Climate Heat Pumps
- Heat Pump Water Heaters
- Weatherization
 - Market Rate
 - Low Income
- Renewable Generation
 - New Net-Metering Installations
 - New In-State Solar Resources that Qualify Under Tier II of Vermont's RES
- Advanced Wood Heating
 - Pellet Stove
 - Pellet Furnace
 - Pellet Boiler

Example: Cold Climate Heat Pump (Single Zone)

SELECT



Nameplate Capacity (BTU/hr)
6,000 – 24,000

Incentive Amount
[\$500] [\$750] [\$1,000]

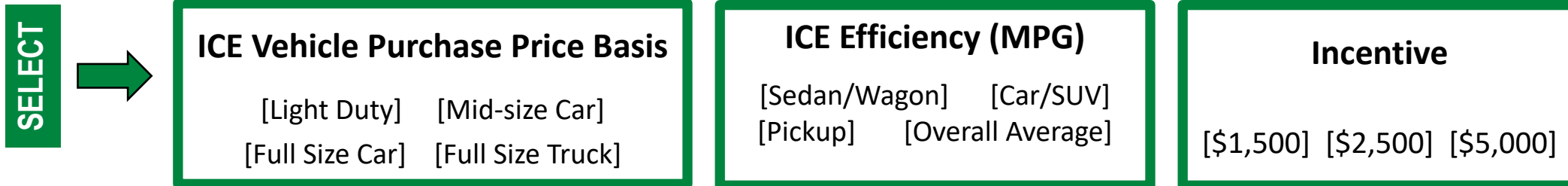
Net Costs	Costs	Benefits
	Purchase Price & Installation	Avoided Fossil Fuel Costs
	Electricity Costs for Heat Pump	

Net Carbon	Carbon Increases	Carbon Reductions
	Added Electricity Consumption (kWh * ISO New England Marginal Emissions Rate * Share of Electricity Fossil Free Generation)	Avoided Fossil Fuel Combustion (EIA CO ₂ Emissions Coefficients)

Example: Cold Climate Heat Pump (Single Zone)

Societal Test - Cold-Climate Heat Pump	Incentive Level											
	\$500 Select One											
	Low	\$500										
	Med	\$750										
	High	\$1,000										
Nameplate Capacity - Btu/hr	12000 Select One											
						Total Installation Cost	\$3,352					
						Lifetime Fuel Savings	\$2,495					
ccHP Societal Cost Test	Totals					Single Zone ccHP Resource Cost Test						
Year	15	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	
MWH Consumed	28.35625	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	
NEPOOL GIS Residual Mix - lbs/MWH		732	732	732	732	732	732	732	732	732	732	
Utilities Fossil Free Percentage		55%	59%	59%	59%	63%	63%	63%	67%	67%	67%	
MWH Not Covered by RES/FFF		0.8507	0.7751	0.7751	0.7751	0.6995	0.6995	0.6995	0.6238	0.6238	0.6238	
Emissions from non-Covered MWH - lbs of CO2	5,795	623	567	567	567	512	512	512	457	457	457	
Annual MMBtu Avoided	236	16	16	16	16	16	16	16	16	16	16	
Avoided Fossil Fuel Emissions - lbs of CO2	27,471	2,301	2,301	2,301	2,301	2,301	2,301	2,301	2,301	2,301	2,301	
Avoided FF Costs	\$4,684	\$334	\$347	\$355	\$363	\$373	\$388	\$398	\$405	\$414	\$418	
Added Electric Costs	\$2,189	\$130	\$153	\$167	\$171	\$180	\$190	\$191	\$194	\$200	\$204	
Total Emissions - Lbs of CO2		21,676										
Cost - \$/Ton CO2		\$79.07										

Example: Electric Vehicle (AEV & PHEV)

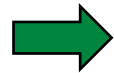


Net Costs	Costs	Benefits
	Purchase Price Premium	Maintenance Savings
	Electricity Costs for Charging Vehicle	Reduced/Eliminated Fossil Fuel Purchases
Net Carbon	Carbon Increases	Carbon Reductions
	Added Electricity Consumption (kWh * ISO New England Marginal Emissions Rate * Share of Electricity Fossil Free Generation)	Avoided Fossil Fuel Combustion

Note: EV purchase prices are based on vehicles available in Vermont, but not weighted based on VT sales.

Example: Solar Net Metering

SELECT



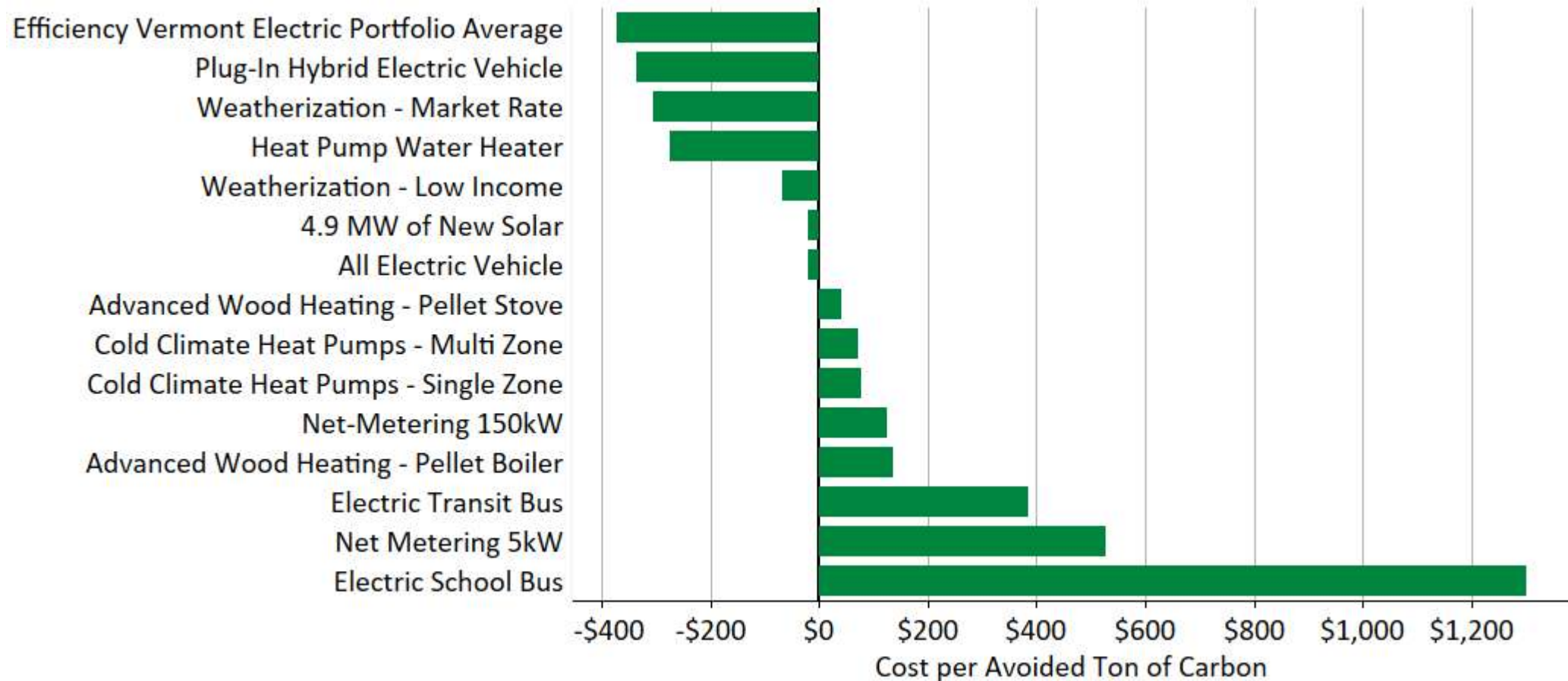
System Size
1 kW – 500 kW

Net Metering System Category	Installation Cost
Small (e.g. 5 kW)	\$2.70 per Watt
Medium (e.g. 150 kW)	\$1.83 per Watt
Large (e.g. 500 kW)	\$1.83 per Watt

	Costs	Benefits
Net Costs	Construction Costs	Energy
	Integration Costs	Forward Capacity and RNS Cost (Coincidence Decreasing Over Time)
		Renewable Energy Credits
		Ancillary Benefits, Market Price Response
	Carbon Increases	Carbon Reductions
Net Carbon		Avoided Generation (kWh generated * NEPOOL residual mix * non-fossil percentage)

Initial Results

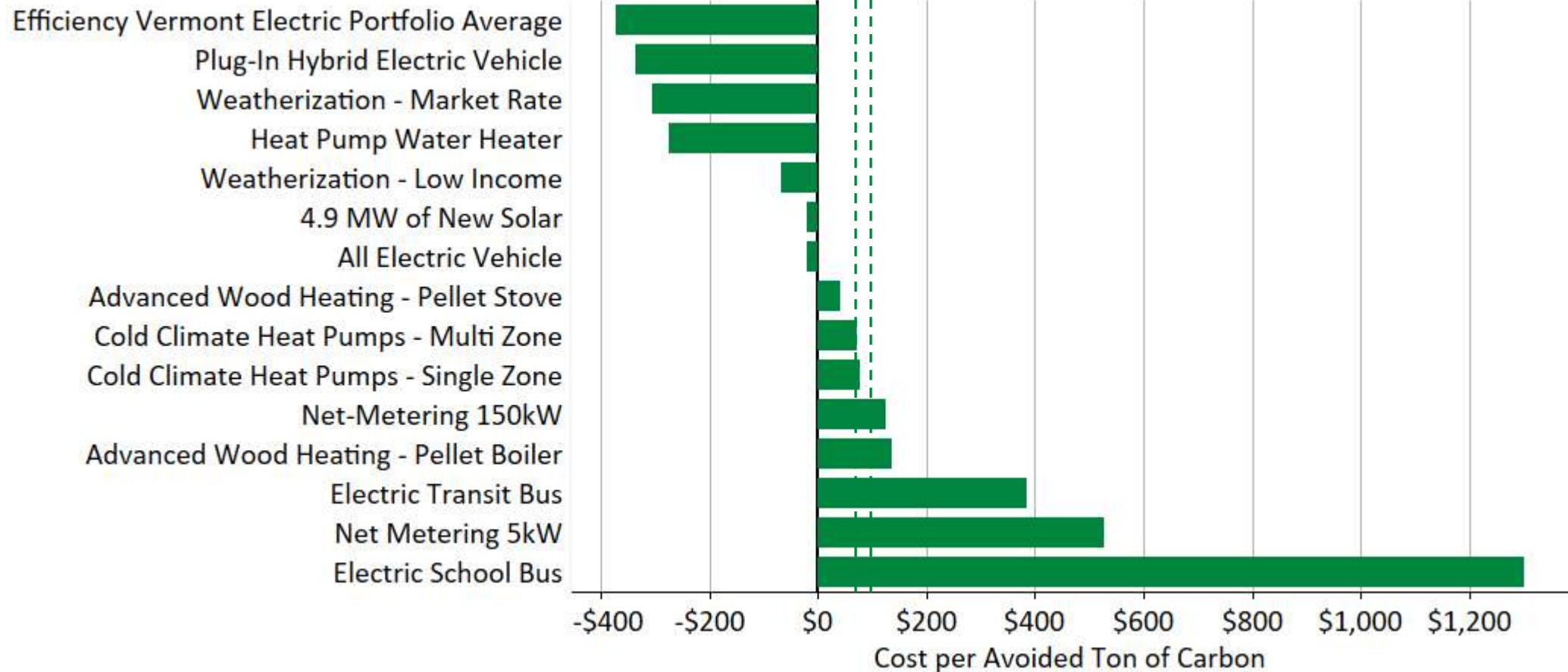
Negative Value per Ton is Good:
Savings Are Greater than Costs



Initial Results

\$68/ton:
New England marginal abatement cost
(Synapse estimate for off-shore wind)

\$100/ton:
Global marginal abatement cost to limit
warming to 2°C (McKinsey estimate)



Considerations

- First draft – some inputs will be revised
- 7 of 15 measures provide net benefit to society
- “Expensive” carbon reduction measures have high incremental cost or incentive structure relative to carbon savings
 - Technologies may cost much less in the future
 - Compensation / incentive levels may rise or fall in the future
- Measures do not include all benefits for Vermont
 - Energy affordability
 - Economic development
 - Health & safety improvements
- Reach GHG goals in most cost-effective way given limited resources
 - Need diversity of complimentary programs serving each sector
 - Some programs (low income weatherization) serve the most vulnerable Vermonters¹⁵

Contact

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Draft Summary Table

12/7/2019
Subject to Revision

Selected Assumptions for Summary Table	
Fossil Free Scenario for Future Electricity Purchases	Base Case - RES
Internal Combustion Engine Type - MSRP	Light-Duty Average
Internal Combustion Engine Type - MPG	Car/SUV
EV Incentive Amount	\$5,000
Electric Bus Incentive	\$50,000
Cold Climate Heat Pumps - Single Zone - Nameplate Capacity BTU	12,000
Cold Climate Heat Pumps - Multi Zone - Nameplate Capacity BTU	18,000
Cold Climate Heat Pump Incentive	\$500
Heat Pump Water Heater – Tank Size	< 55 Gallon
Heat Pump Water Heater – Incentive	\$500

Measure	CO2 Avoided (Tons) <i>per measure</i>	Net Resource Cost <i>per measure</i>	\$/Ton Avoided
4.9 MW of New Solar	14,909	\$5,194,000	(\$21)
Electric Transit Bus	617	\$236,812	\$384
Net-Metering 150kW Solar System	319	\$274,500	\$125
Electric School Bus	169	\$219,388	\$1,301
Advanced Wood Heating - Pellet Boiler & Furnace	123	\$16,323	\$137
Weatherization - Market Rate	88	(\$26,731)	(\$305)
Advanced Wood Heating - Pellet Stove	80	\$3,366	\$42
Weatherization - Low Income	46	(\$3,104)	(\$68)
All Electric Vehicle	45	(\$913)	(\$20)
Plug-in Hybrid Electric Vehicle	23	(\$7,709)	(\$337)
Cold Climate Heat Pumps - Multi Zone	14	\$1,012	\$74
Net Metering 5kW	11	\$5,628	\$528
Cold Climate Heat Pumps - Single Zone	11	\$857	\$79
Heat Pump Water Heater	5	(\$1,437)	(\$275)
Efficiency Vermont Electric Portfolio Average	0.221	(\$78)	(\$372)