Summary of VPIRG Report "Repowering Vermont by 2032" Capital costs calculated by Coalition for Energy Solutions using CES assumptions																
	Existing Conditions					Moderate Renewables					Strong Renewables					
						Moderate Efficiency					Strong Efficiency					
						No VT Yankee					No VT Yankee					
		Supply	gWh	Add'l	CO2		Supply	gWh	Add'l	CO2		Supply	gWh	Add'l	CO2	
		%		Cap'l			%		Cap'l			%		Cap'l		
				Cost					Cost					Cost		
				$Billion					$Billion					$Billion		
Traditional electricity consuption			6134					5943.0					5311.0			
Electricity for transportation			0					357.0					3089.0			
Total electricity supply; see notes			6134					6300.0					8400.0			
VT Yankee; Existing from Dept of P. S. 2006		34.0	2086	0.00	0											
Wind small scale, mW	0.1					66.0		41.0	0.33		66.0		41.0	0.33		
Wind new large scale; Existing Searsburg, mW	6.0					542.0		1422.0	1.36		863.0		2264.0	2.16		
Wind turbines @ 10 kW each, thousands	0.1					6.6					6.6					
Wind turbines @ 3,000 kW each						181.0					288.0					
Ridge line needed @ 6 turbines/mile, miles						30.2					48.0					
Wind production; Existing from DOE 2008		0.2	10	0.00	0		23.2	1463.0		0		27.4	2305.0		0	
Hydro Quebec; Exist'g fr. Dept of P. S. 2006		27.0	1656	0.00	0		30.6	1930.0	0.00	0		24.2	2030.0	0.00	0	
VT Hydro, mW	113.0					113.0			0.00		113.0			0.00		
VT Hydro production; Existing from DOE 2008		12.7	781	0.00	0		7.8	493.0		0		5.9	493.0		0	
Solar large scale 50 kW and up, mW	1.0					285.0			1.43		855.8			4.28		
Solar small scale 3 kW - 10 kW, mW	0.4					57.0			0.29		171.2			0.86		
Houses if 3 kW solar systems, thousands	0.2					13.3					40.0					
Panel area required, sq. miles						0.98					3.70					
Solar production; Existing from DOE		0.1	6	0.00	0		6.8	430.0		0		15.4	1290.0		0	
Wood, Ryegate plant, mW	20.0					20.0					20.0					
Wood, McNeil plant, mW	53.0					53.0					53.0					
Wood, New plants, mW	3.0					3.0					3.0					
Wood, 2032 New Plants, mW						171.3			0.60		171.3			0.60		
Wood, total mW; Existing data from DOE 2008 website	76.0					247.3					247.3					
Cords of wood required by plants, thousands	235.9					767.3					767.3					
VT acres needed @ 0.5 cord/acre, thousands	314.5					1023.1					1023.1					
Wood production; Exisitng data from DOE 2008 website		6.9	424				21.9	1379.0				16.4	1379.0			
Farm biomass, mW	0.1					20.0					45.0					
Farm biomass production*		0.1	6				2.0	126.0				4.0	335.0			
Landfill methane, mW	3.6					19.0					19.0					
Landfill methane production		0.6	36				2.4	150.0				1.8	150.0			
Market purchases		18.4	1129				4.7	296.0				5.0	418.0			
Total		100.0	6134	0.00	0		99.5	6267.0	4.00	0		100.0	8400.0	8.22	0	

Notes:

WIND

Installed cost of a 10 kW wind turbine system on an 80-ft mast is assumed at $40,000. Capacity factor = (6,094 + 192) kWh/yr/(10 kW x 8,760 hr/yr) = 0.0712

http://www.greenbuildingadvisor.com/homes/energy-comes-sun-wind-and-earth-vermont-leed-platinum-home

Installed cost of a ridge-mounted 3,000 kW wind turbine is assumed at $7.5 million, incl. roads and connecting to distribution systems.

Moderate Case: 1,463 gWh/6,300 gWh x 100 = 23.2%. Strong Case: 2,305 gWh/8,400 gWh x 100 = 27.4%

The C.F.s of the 5 operating new wind farms in Maine, which has better winds than Vermont, are 0.29 - 0.32, with one, Mars Hill, at 0.36

New wind farms on Vermont's main north-south ridge line, mostly in Wind Classes 4, 5 and 6, will likely have capacity factors of about 0.29 - 0.32

See "Maine Wind Farms" spreadsheet with websites I used C.F. = 0.30 for this spreadsheet.

Moderate and Strong Case, Small Wind: 66 mW x 8,760 hrs/kW x 0.0712 capacity factor = 41 gWh. Capital cost = 66 mW x $5,000/kW = $0.33 billion

Moderate Case, Big Wind:: 542 mW x 8,760 hrs/kW x 0.30 capacity factor = 1,422 gWh. Capital cost = 542 mW x $2,500/kW = $1.355 billion

Strong Case, Big Wind: 863 mW x 8,760 hrs/kW x 0.30 capacity factor = 2,264 gWh. Capital cost = 863 mW x $2,500/kW = $2.158 billion

PV SOLAR

Vermont is assumed to have 620,000 people/3 people per household = 200,000 houses

VPIRG assumes: Moderate Case 1 in 15 houses with PV system, 13,000 houses; Strong Case 1 in 5 houses with PV systems, 40,000 houses

I used $5,000/kW for its report, because cost/kW will continue to decline in future years. I used 12.5 W/sq ft for its report Current PV solar costs = $6,500/kW

Vermont average insolation is about (3,800 - 4,400 Wh/sq m/d)/(24 h/d) = 158 - 183 W/sq m = 14.7 - 17 W/sq ft http://www.thermomax.com/American_Solar_Energy.php

A typical PV panel produces about 130 - 145 W/sq m = 12 - 13.5 W/sq ft More efficient panels, say 15 -18 W/sq ft, are more expensive.

http://solarbythewatt.com/2009/04/19/physical-area-efficiency-of-solar-photovoltaic-panels-or-watt-per-square-foot/

Maximum output from a PV system in Vermont = 1 kW x 4.3 avg hrs peak sun/d x 365 d/yr x 0.80 eff = 1,256 kWh/yr/kW

I calculate Moderate Case PV capacity = 430,000,000 kWh/yr x 1/(1,256 kWh/yr/kW) = 342 mW. Capital cost = 342 mW x $5,000/kW = $1.71 billion

I calculate Moderate Case panel area = 342,000,000 W/(12.5 W/sq ft x 1/27,880,000 sq ft/sq mile) = 0.98 sq miles

I calculate Strong Case PV capacity = 1,290,000,000 kWh/yr x 1/(1,256 kWh/yr/kW) = 1,027 mW. Capital cost = 1,027 mW x $5,000/kW = $5.14 billion

I calculate Strong Case panel area = 1,290,000,000 W/(12.5 W/sq ft x I/27,880,000 sq ft/sq mile) = 3.7 sq miles

WOOD

Capital cost of wood chip-fired power plants, greenfield site, are $3,000 - $4,000/kW CES uses $3,500/kW for its report

Source: Biomass Power for Utility Applications, Southern Company Experience, by Tom Johnson, Research Program Manager, twjohnso@southernco.com

Heating value of low grade green wood chips = 9,400,000 Btu/ton, or 23,500,000 Btu/cord. http://www.biomasscenter.org/pdfs/Wood-Chip-Heating-Guide.pdf

Cord weight of low grade green wood chips = 5,000 lb = 2.5 ton.

0.5 cord/acre is allowed to be harvested to conform with sustainable forestry practice. One sq mile = 640 acres = 27,880,000 sq ft

Vermont 2005 wood harvest = 804,872 cords. Timberland: public = 919,000 acres, private = 4,000,000 acres Source: website of VT Dept of Forests, Parks, Recreation

Existing wood power plant 2008 output = 76 mW x 8,760 hrs/yr x 0.638 capacity factor = 424 gWh/yr. Source: US DOE website, 2008, VT, 235,900 cords/yr, 76 mW, 424 gWh/yr

Existing wood power plant 2008 output = 235,935 cords x 23,500,000 Btu/cord x 1 kWh/3,413 Btu x 0.261 plant efficiency = 424 gWh/yr

McNeil power plant output = 340,000 ton/yr x 9,400,000 Btu/ton x 1 kWh/3,413 Btu x 0.261 = 244 gWh/yr. Source: The Vermont Wood Fuel Supply Study June 21,2007

Ryegate power plant ouput = 250,000 ton/yr x 9,400,000 Btu/ton x 1 kWh/3,413 Btu x 0.261 = 180 gWh/yr. Source: The Vermont Wood Fuel Supply Study June 21,2007

About 1/3 of wood for McNeil and Ryegate is from out-of-state, i.e., NY and NH Source: The Vermont Wood Fuel Supply Study June 21,2007

CES assumes 1/3 of wood for new plants will be from out-of-state.

Wood plant 2032 output = 767,348 cords x 23,500,000 Btu/cord x 1 kWh/3,413 Btu x 0.261 plant efficiency = 1,379 gWh/yr

Vermont area harvested in 2032 = existing uses + added for new power plants = 1,609,744 + (1,023,100 - 314,500) = 2,318,344 acres = 3,622 sq miles

Vermont's total area = 9,615 sq miles, incl. water area

VPIRG calculates: 176 mW x 8,760 hrs/yr x 0.896 capacity factor = 1,379 gWh/yr. The C.F. is too high. See above C.F. Capital cost = 100 mW x $3.500/kW = $0.35 billion

CES calculates: 247.3 mW x 8,760 hrs/yr x 0.638 capacity factor = 1,379 gWh/yr. The 0.638 capacity factor is from existing VT wood plants

CES calculates: Add'l capacity required = 247.3 mW - 76 mW = 171.3 mW. Capital cost = 171.3 mW x $3,500/mW = $0.6 billion