Summary of VPIRG Report "Repowering Vermont by 2032" Capital costs calculated by Coalition for Energy Solutions using Report 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					5311			
Electricity for transportation			0					357					3089			
Total electricity supply; see notes			6134					6300					8400			
VT Yankee; Existing from Dept of P. S. 2006		34.0	2086	0.00	0											
Wind small scale, mW	0.1					66.0		41	0.33		66.0		41	0.33		
Wind new large scale; Existing Searsburg, mW	6.0					430.0		1422	1.09		700.0		2264	1.76		
Wind turbines @ 10 kW each, thousands	0.1					13.2					13.2					
Wind turbines @ 3,000 kW each						145.0					235.0					
Ridge line needed @ 6 turbines/mile, miles						24.0					39.0					
Wind production; Existing from DOE 2008		0.2	10	0.00	0		23.2	1463		0		27.4	2305		0	
Hydro Quebec; Exist'g fr. Dept of P. S. 2006		27.0	1656	0.00	0		30.6	1930	0.00	0		24.2	2030	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		5.9	493		0	
Solar large scale 50 kW and up, mW	1.0					205.0			1.03		614.0			3.07		
Solar small scale 3 kW - 10 kW, mW	0.4					40.0			0.20		120.0			0.60		
Houses if 3 kW solar systems, thousands	0.2					13.3					40.0					
Panel area required, sq. miles						0.9					2.6					
Solar production; Existing from DOE		0.1	6	0.00	0		6.8	430		0		15.4	1290		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						100.0			0.35		100.0			0.35		
Wood, total mW; Existing data from DOE 2008 website	76.0					176.0					176.0					
Cords of wood required by plants, thousands	235.9					667.6					667.6					
VT acres needed @ 0.5 cord/acre, thousands	314.5					1335.2					1335.2					
Wood production; Exisitng data from DOE 2008 website		6.9	424				21.9	1379				16.4	1379			
Farm biomass, mW	0.1					20.0					45.0					
Farm biomass production*		0.1	6				2.0	126				4.0	335			
Landfill methane, mW	3.6					19.0					19.0					
Landfill methane production		0.6	36				2.4	150				1.8	150			
Market purchases		18.4	1129				4.7	296				5.0	418			
Total		100.0	6134	0.00	0		99.5	6267	2.99	0		100.0	8400	6.11	0	

Notes:

Data for Moderate Case and Strong Case are from the VPIRG report. Existing Conditions, not in the VPIRG report, were added for reference.

Electricity for transportation is for future plug-in hybrids and all-electric vehicles.

GMP and CVPS buy from VT Yankee @ 3.9 - 4.5 c/kWh under long term contracts. Source: VT Dept of P. S.

Total electricity consumption in Vermont is 5,883 gWh in 2005 (source: US DOE) and 6,134 in 2008, if escalated at 1.4%/yr.

Supply percentages for VT Yankee, Hydro Quebec, VT Hydro and Wood are from US DOE and VT Dept of P. S.

* 49 gWh is stated in the VPIRG report. Two percent biomass power equals 126 gWh. I used 126 gWh which makes 6,267 gWh/yr closer to 6,300 gWh/yr at the top.

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.

VPIRG calculates Moderate and Strong Case: 66 mW x 8,760 hrs/yr x 0.0712 capacity factor = 41 gWh.

VPIRG calculates Moderate Case: 430 mW x 8,760 hrs/yr x 0.378 capacity factor = 1,422 gWh.

VPIRG calculates Moderate Case: 700 mW x 8,760 hrs/yr x 0.369 capacity factor = 2,264 gWh.

C.F.s are too high. Wind farms in the Dakotas, etc., have capacity factors of 0.35 - 0.40

PV SOLAR

For analysis of the VPIRG report, Vermont has 620,000 people/3 people per household = 200,000 houses.

VPIRG assumes Moderate Case: 1 in 15 houses with PV system, or 13,000 houses. Strong Case: 1 in 5 houses with PV systems, or 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, or 1 kW x 8,760 hrs/yr x CF 0.143 = 1,256 kWh/yr

WOOD

Capital cost of wood chip-fired power plants, greenfield site, are $3,000 - $4,000/kW I use $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

I assume 1/3 of wood for new plants will be continue to 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

I calculate: 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

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