VALMONT REPOWERING STUDY

<u>Developed for:</u>

City of Boulder

Boulder County

<u>Developed by:</u>

First Tracks Consulting Service, Inc.

Iron Mountain Consulting

July 1, 2010

Overview

The City and County of Boulder retained First Tracks Consulting, Inc. and Iron Mountain Consulting, Inc. to evaluate potential repowering alternatives for Valmont Unit 6, a 186 MW steam generator owned by Xcel Energy and located in Boulder, Colorado. The original project intent was to develop policy proposals, particularly related to the City's and County's aggressive Carbon Action Plans, to be pursued in Xcel Energy's 2010 (Interim) IRP docket before the Colorado Public Utilities Commission (PUC). Subsequently, H.B. 1365 was passed by the Colorado Legislature and signed into law by Governor Ritter, requiring Xcel Energy to reduce nitrogen oxide (NO_x) emissions on the Front Range over the next seven years. The PUC opened a new Docket for H.B. 1365, which became the focus of the City's and County's advocacy strategy.

Xcel Energy is working with the Colorado Department of Public Health and Environment and other parties to submit plans by Aug. 15 to the PUC that reduce NO_x emissions at metro area coal plants by 70% to 80% by Dec. 31, 2017. Xcel Energy's plan will include an evaluation of retiring or retrofitting 900 megawatts of Front Range coal-fired capacity, including Valmont, giving primary consideration to replacing or repowering those plants with natural gas, renewable energy and other lower-emitting resources.[1] Beyond reducing NO_x emissions, the City and County remain interested in seeing Valmont Coal Unit 6 repowered to help meet their aggressive Carbon Action Plans as well as to help stimulate overall sustainability and commercialization of utility-scale renewable energy technologies.

To help the City and County better understand the potential for emissions reduction at Valmont, this study identified and analyzed 18 different renewable and natural gas options for repowering Valmont Unit 6. For each option, the study calculated the expected power output at the site, the replacement power purchases required to compensate for any reduced output compared to the existing coal plant, lifecycle costs, and annual emissions. Based on this information, the study identified the most attractive options for the City and County to pursue in advancing their overall air quality goals.

Key Findings

This study shows that there are a number of viable options for reducing carbon, NO_x, and other emissions at the Valmont site. The most attractive renewable options for the site include:

- Stand-alone biomass options;
- A hybrid coal/wood option involving retrofitting burners in the existing coal plant to burn high-quality wood fuel; and
- Hybrid fossil/solar thermal options tied to either the existing coal configuration or to a new combined cycle plant constructed at the site.

[1] Clean Air Clean Jobs Bill http://www.colorado.gov/cs/Satellite?c=Page&childpagename=GovRitter%2FGOVRLayout&cid=1251573201310&pagename=GOVRWrapper

Other key findings include:

- Replacing the existing Valmont output with output from natural gas combined cycle plants—either new plants constructed at the Valmont site, or a portion of a larger plant constructed elsewhere—can also produce substantial emissions reductions.
- Because of Valmont's close proximity to the mountains, and due to the high rate of beetle infection among lodgepole and ponderosa pines in Colorado, there is a large amount of high quality, woody biomass fuel available to be used at Valmont. The biomass repowering scenarios are carbon neutral, reduce NO_x and SO_x emissions, and can be operated as firm, dispatchable resources.
- While Boulder County does not have optimal solar resources, adding solar collector arrays (parabolic troughs) to add steam to a fossil plant is also an effective way to leverage resources and reduce emissions.
- Due to size constraints, the Valmont site is not an effective host for wind turbines or photovoltaics (PV). Because these technologies do not operate in conjunction with other on-site generation infrastructure, there is little reason to locate them on this site, with suboptimal resources and little available space.
- The findings do not change substantially under sensitivity testing of results to assumptions about future carbon taxes or higher fuel costs. In the sensitivity cases, all repowering options are more attractive compared to the existing Valmont coal option (that is, the sensitivity assumptions have the largest impact on Valmont's lifecycle costs), but the relative ranking of options is unchanged (that is, the same "best options" still emerge).
- Adding a carbon tax consistent with a U.S. Environmental Protection Agency (USEPA) analysis of recent federal climate change legislation more than doubles the cost of combusting coal at Valmont

Methodology and Approach

The objectives of this study are to identify a list of viable repowering options and to then analyze the technical specifications, long-term economics, and emissions profiles of each option. The objective is not to make final investment decisions or select "resource winners." Instead, this study helps the City and County to be more strategically informed about the characteristics of the Valmont site and the features of possible new electric generation options at that site when working with Xcel and other parties to the H.R. 1365 proceeding.

Options Considered

We limit the scope of the study strictly to repowering options for Valmont Unit 6, and do not attempt to model other resources at the Valmont site (e.g., three combustion turbines at the site) or the larger mix of resources in Xcel's generation portfolio. Repowering options include renewable technologies appropriate for the site (e.g., no hydroelectric or geothermal options were considered), natural gas options, as well as "hybrid" options that combine renewable technologies with coal or natural gas options. While additional alternatives might also be viable for the site (i.e., future "clean coal" technologies; additional NO_x emissions controls), they were beyond the scope of this analysis.

Table 1 outlines the list of options included in the analysis, including variation by fuel (or renewable resource) and technology. Overall, 11 fuel/technology combinations were analyzed, including 2 options using the existing Valmont Unit 6, 5 repowering options, and 4 hybrid options. For certain options, additional scenarios were created to evaluate uncertainties regarding the capacity or energy that could be generated at the site. With these variations, a total of 18 different repowering scenarios were evaluated.

Table 1
Repowering Options

Fuel Type	Technology Type	Capacity Output		Energy Output	
		Small	Large	High	Low
Existing Valmont Plant Options					
Coal	Steam Turbine				
Natural Gas	Steam Turbine				
Repowering Options					
Natural Gas	Combined Cycle	✓	✓	✓	✓
Solar	Photovoltaic	✓	✓	✓	✓
	Parabolic Trough	✓	✓		
Wind	Conventional Turbine				
Biomass	Fulidized Bed	✓	✓		
Hybrid Repowering Options					
Biomass/Coal	Steam Turbine				
Biomass/Natural Gas	Combined Cycle/Steam Turbine				
Solar/Coal	Parabolic Trough/Steam Turbine				
Solar/Natural Gas	Parabolic Trough/Combined Cycle				

Evaluation

A model was created to estimate the fuel use, cost, and emissions associated with each repowering option. In order to create "apples-to-apples" comparisons of repowering options that produce different energy or capacity output, all options were normalized to the output of the existing Valmont coal configuration, which produces 186 MW at an annual capacity factor of approximately 74%. Options with less output than the existing plant were assumed to purchase replacement power to make up the difference; options with higher output were assumed to sell the excess.

The model requires technical and cost inputs for each repowering option, which are discussed in more detail in the next section. In addition, the model includes forecasts of fuel prices, prices for replacement power purchases and market sales, and emissions costs, each of which were developed for a base case, as well as sensitivity scenarios. These prices were developed from multiple sources, including U.S. Department of Energy (USDOE) forecasts for power plant fuels[2], Xcel's recent forecast of its avoided costs[3], discussions with Colorado biomass fuel suppliers, USEPA data on sulfur emission costs[4], and USEPA forecasts of potential future carbon costs[5].

Existing Valmont Site

The Valmont site contains four power plants, including Valmont Unit 6, the 186 MW coal plant that is the focus of this study, as well as three additional combustion turbines with a combined capacity of approximately 120 MW. The site itself covers approximately 550 acres, much of it taken up by three ponds central to the Unit 6 cooling system.

The site also contains the electric transmission infrastructure necessary to link the plants to Xcel's wider electric grid, as well as the fuel supply infrastructure necessary to provide the coal and natural gas necessary for plant operations. Unit 6 is currently capable of running on either coal or natural gas, although it operates almost entirely on coal from western Colorado mines.

Xcel has installed a number of emissions controls on Unit 6, including SO_x scrubbers installed in 2001, and baghouse particulate control and low-NO_x burners, both installed in the 1990s.

Repowering Options

This section discusses key features of the repowering options, and also identifies the acronyms used to label each option in the charts used to present results. The Appendix provides tables with additional details regarding assumptions and results for each repowering option.

Existing Valmont Coal Plant. This option involves making no changes to Valmont Unit 6, and continuing to operate it at a 74% capacity factor. It is the scenario that requires the least investment, creates no stranded assets, and involves little engineering risk. This scenario serves as a baseline for calculating the costs and emissions savings associated with the other repowering options. For consistency with the other repowering alternatives considered in the study, we assume that the large equipment at Valmont (e.g., boiler, turbines) will not have to be replaced in the 30-year horizon of our study.

Acronym: Valmont Coal

Valmont Gas. This option involves using the existing natural gas infrastructure at the plant to operate it on natural gas instead of coal. For the analysis, we assume that the plant could continue to operate at its current 74% capacity factor. Again, this scenario requires no investment, creates no stranded assets, and involves little engineering risk. It does create additional fuel price risk however, since natural gas prices have historically been much more volatile than coal prices.

Acronym: Valmont Gas

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[2] USDOE, Energy Information Administration, *Annual Energy Outlook, 2010*.

[3] KEMA, Inc., *Colorado DSM Market Potential Assessment, Final Report Appendices*, prepared for Xcel Energy.

[4] USEPA, 2010 Acid Rain Allowance Auction Results, www.epa.gov/airmarkets/trading/2010.

[5] USEPA, Supplemental EPA Analysis of the American Clean Energy and Security Act of 2009 *H.R. 2454 in the 111th* Congress.

Photovoltaics. These repowering scenarios involve demolishing much of the existing coal plant and surrounding buildings and freeing up land for PV installation. To bound the analysis, we assume two different amounts of land area could be made available at the Valmont site: on the low end, 150 acres and, on the high end, 400 acres. (The 400 acre scenario would require filling in or building over some of the reservoir.) We also considered both flat-plate and tracking panels, with the tracking technology allowing for a greater capacity factor and energy output. Thus, we modeled four PV scenarios: tracking and fixed panels covering 150 acres of land, and tracking and fixed panels covering 400 acres.

These systems have the benefit of zero emissions and almost zero local environmental impacts, as well as the availability of federal investment tax credits that reduce initial costs. PV systems can also utilize diffuse light (better than solar thermal systems, described below), which is common in Boulder during cloudy, summer afternoons. While the PV options leverage existing assets and reduce transmission and land costs, Boulder County does not have ideal solar insolation, meaning that there are better PV sites elsewhere on Xcel's system. Moreover, these scenarios reduce annual energy output from the site, requiring large amounts of make-up power and capacity to be purchased from elsewhere on the system. And while PV systems do generate power during peak load, they provide a fairly low peak-contribution (only 45%-55% of installed capacity).

Acronyms: PV150F, PV400F, PV150T, PV400T

Solar Thermal. These scenarios involve demolishing much of the existing coal plant and surrounding buildings and freeing up land for stand-alone solar thermal installations. Solar thermal systems capture the heat of the sun and store it in a heat transfer fluid, which is used to generate steam to create power in a steam turbine. These scenarios assume "stand-alone" systems, although below we consider additional hybrid systems. We model parabolic trough systems with four hours of storage. Similar to the photovoltaic options described above, we model one scenario assuming 150 acres of available land, and a second scenario assuming 400 acres.

The solar resource, once again, is not ideal in Boulder County, where it is often cloudy in the summertime (especially relative to more optimal solar sites). Unlike PV, solar thermal systems reduce their output when clouds obstruct direct insolation. However, similar to the PV scenario described above, the solar thermal option requires purchasing considerable make-up power and capacity to match Valmont's existing output. Nonetheless, this technology can take advantage of the solar investment tax credit and has zero emissions. Finally, with four hours of storage, it can contribute 100% of its capacity to meeting peak load.

Acronyms: Trough150 and Trough400.

Wind. We assume the site is capable of hosting three towers, with large, 2 MW turbines on each tower. This repowering scenario envisions constructing a 6-MW wind farm on the site, likely siting the towers in the existing reservoirs, and foregoing the expense needed to demolish the existing Unit 6. We note that wind turbines do pose a threat to existing wildlife, in particular great-horned owls which have nests around the site. Wind turbines also pose a threat of creating noise disturbance.

This repowering scenario, like the solar scenarios, is compromised by the suboptimal renewable resource in Boulder County. Given that the wind turbines would not be operating in hybrid with any on-site plants, Xcel is likely to find other sites with the potential for much larger capacity and much better capacity factors, thereby greatly leveraging its wind investment. In addition, wind shows a relatively poor peak contribution at 10% of installed capacity. However, like the solar options, wind can take advantage of federal subsidies—this time in the form of a production tax credit—and produces electricity with no air emissions.

Acronym - Wind

Biomass. This option involves replacing the existing coal plant with a stand-alone fluidized bed biomass plant. We selected fluidized bed instead of alternative stoker technologies, because, for similar costs, it offers flexibility in fuel supply as well as superior NO_x performance. The fuel can be woody biomass (i.e., dead trees, municipal wood waste, etc.) or other forms of biomass (municipal solid waste, agricultural waste, etc.), and the fluidized bed process can accept wood with varying moisture content and quality, lowering fuel costs. And the lower combustion temperatures used by the fluidized bed technology greatly reduce NO_x emissions.

We model two options: 186 MW of circulating fluidized bed (to replace Valmont with equal capacity and energy), assuming there is enough long-term fuel supply to warrant this size; and 100 MW bubbling fluidized bed plant, assuming the fuel supply is more limited. Both cases assume operation at Valmont's current 74% capacity factor. And both cases assume that wood and other biomass with minimal quality requirements (e.g., high moisture content, large diameter chips) could be delivered to the site at a price of $35 per ton. The smaller plant would likely require demolition of the existing Unit 6; the larger option could leverage some infrastructure from Unit 6.

There are a number of fuel supply issues with biomass, both constraints and opportunities. Colorado's forests have been severely impacted by a few strains of bark beetles that are infecting hundreds of thousands of acres. Many foresters believe these trees need to be removed to prevent forest fires and for forest health, but there is little market for this waste biomass. It is unclear how much usable woody biomass is available to be delivered for combustion at the Valmont site over the long term, and at what price point. Because of this uncertainty, we model stand-alone scenarios with two different size plants, as well as hybrid scenarios (described below), with yet smaller biomass fuel requirements.

The benefits of generating electricity from biomass fuels include that it is carbon neutral[6], has low NO_x and sulfur emissions, stimulates job creation in rural areas, and can operate as a firm, reliable, baseload resource (i.e., replaces Valmont well). These systems can leverage some of the existing infrastructure currently at the Valmont site, and they also can take advantage of the federal biomass production tax credit.

Some of the challenges include addressing the long-term fuel supply uncertainty and fuel delivery issues (i.e., noise and dust from trucks, using trains, etc.). In addition, while existing national and international agreements specify that biomass plants relying on sustainably forested fuel supply produce zero net emissions, not everyone agrees that these plants are truly carbon neutral. Biomass plants also produce additional air emissions that are of concern.

Acronyms – Biomass 186 and Biomass 100.

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[6] While biomass generation emits carbon during combustion, virtually all national and international agreements specify that biomass plants relying on sustainably forested fuel supply produce zero net carbon.

Natural Gas Combined Cycle. The combined cycle scenarios involve replacing the output from Valmont Unit 6 with output from new, natural gas fired, combined cycle units. Two "on-site" scenarios involve converting Unit 6 to a gas-fired, 2x1 combined-cycle unit. We model a design that is sized to use the existing boiler, as well as sized to operate within the limitations of the existing cooling system at the Valmont site. We model a system that incorporates two 185 MW combustion turbines and a heat recovery steam generator (HSRG) producing another 185 MW, for a total of 555 MW. We model two on-site scenarios: one operating at 40% capacity factor (intermediate load) and a second at 74% capacity factor (base load).

We also model an "off-site" scenario that more closely matches the output of the existing Valmont coal plant, that is, a 186 MW plant operating at 74% capacity factor. While a 186 MW plant would be sub-optimally sized for most new plants, Xcel might choose to build a larger combined cycle facility at another existing coal facility, retire the Valmont coal plant, and use 186 MW of output from the new facility to replace the historic Valmont output.

New combined cycle units create a range of benefits. They provide relatively low emissions, and firm power with output that can be ramped up or down quickly, which make them highly valuable as "load following" resources. They are also highly efficient; with modern combustion turbines providing heat rates approaching 10,000 Btu/kWh, and recovering waste heat in the steam generator, new combined cycle units have overall heat rates below 7,000 Btu/kWh.

A new on-site unit would also triple the amount of capacity on the same footprint. We assume that both the gas pipeline and the electric transmission capacity would need to be increased in capacity to facilitate this expansion, and adjust capital costs accordingly. We also assume that the excess capacity and excess energy (relative to Valmont Unit 6) would be sold to the market. Finally, we assume the existing boiler can be kept and used in the combined cycle plant—a capital cost savings approaching $50 million.

Challenges associated with combined cycle units include relatively high fuel costs, as well as volatility and unpredictability in future fuel costs and some risk associated with regulation over carbon emissions.

Acronyms – CC 555/40, CC 555/74, CC 186/74

Coal/Solar Thermal. This hybrid scenario involves maintaining the existing Valmont coal unit and adding 12.5 MW of solar thermal parabolic trough capacity on site to add heat to the coal plant's steam cycle and reduce the amount of coal that gets burned. (A parabolic trough plant of this size would require approximately 100 acres of available land.) Though Boulder County does not have an ideal solar resource, the option of adding the solar collector arrays to an existing steam plant is much less expensive than building a stand-alone solar plant (which would require its own power block, meaning the boilers, the turbines, the transmission capacity, etc.). By leveraging the existing fossil infrastructure, a small amount of solar energy can be economically added to the existing plant, reducing fuel costs, and mitigating the risks associated with fuel price volatility and future carbon costs.

Acronym: Coal/Solar

Combined Cycle/Solar Thermal. This hybrid scenario combines the gas-fired combined cycle option described above with a 12.5 MW solar thermal parabolic trough collector array to augment the steam cycle (in the heat recovery steam generator). As discussed for the coal/solar option, this option would require 100 acreas of available land, lowers costs by leveraging the steam and electrical infrastructure of associated fossil plant, and provides a hedge against risks associated with future fuel and carbon costs.

Acronym: CC/Solar

Coal/Wood. This hybrid scenario involves adding a second fuel delivery and fuel injection system at the existing coal unit so that woody biomass can be used to supplement coal for the plant's fuel. The same burners and boilers would be used, but some of the burners would burn wood instead of coal, thus maintaining 186 MW of capacity and reducing carbon emissions. Since the existing Valmont plant was designed to burn coal, and wood would create higher, more corrosive flue gas velocity, there are limits to the amount of wood burning that could be retrofit on the existing plant. We assume a maximum limit of 15% of plant output could be provided by wood combustion. In addition, to accommodate the existing burners at the site, biomass meeting strict quality parameters would be required (e.g., only wood, very low moisture content, very small chip size).

Colorado Springs Utilities is retrofitting its Drake Coal Plant, in the heart of Colorado Springs, to "co-combust" coal and wood in this manner. We imagine a good portion of the wood will come from region infected with the beetle kill virus in the nearby mountains. We estimate that approximately 100,000 tons of wood meeting premium quality standards could be delivered to the Valmont site at a cost of $55/ton.

A benefit of this scenario, relative to the "stand-alone" biomass scenarios described above, is that the cost of retrofitting the current plant to accept 15% wood is not very expensive (roughly $8 million), and it would be a prudent investment even if it only operated for 5 to 10 years. Because there is uncertainty regarding the long-term wood supply, this option would also reduce long-term fuel supply risk.

Risks associated with this scenario include technology risks (Colorado Springs would be the first to successfully apply this biomass combustion approach), as well as higher NO_x emissions than the fluidized bed technologies due to higher combustion temperatures.

Acronym: Coal/Wood

Combined Cycle/Wood. This hybrid scenario combines the combined cycle scenario described above with a small fluidized bed biomass plant that would provide direct heat to supplement the steam created by the heat recovery steam generator. . However, since the direct firing would replace some of the HRSG output, the plant would likely require smaller combustion turbines to optimize HRSG operation, lowering the overall plant capacity relative to the other on-site combined cycle options.

The benefits of this system are that it utilizes available, local biomass resources and lowers the plant carbon intensity. On the other hand, this novel design would introduce new technology risks in addition to the risks associated with biomass fuel supply.

Acronym: CC/Biomass

Market Purchases. This scenario is included in our analysis as a reference point to show the financial and emissions impacts of replacing all of Valmont's capacity and energy output with market purchases. Because some options require substantial market purchases to make up for larger output reductions relative to the exiting Valmont plant, it is helpful to review their cost and emissions results relative to a "100% market" scenario. Market prices are consistent with

Xcel's recent forecast of its avoided costs. Market emissions are calculated assuming operation of combustion turbines during super-peak periods; combined cycle plants during on-peak and mid-peak periods, and coal plants during off-peak periods.

Acronym: 100% Market

Technical and Cost Assumptions

Tables 2 and 3 present the technical and cost assumptions for each repowering option. Repowering assumptions were developed from a wide variety of sources, including public information available from Xcel; information from industry sources such as the USDOE, USEPA, and the National Renewable Energy Laboratory; and direct communication with developers of utility-scale renewable energy projects.

Table 2 provides the technical assumptions used to define each repowering option. Plant capacity output is specified with three assumptions: a nameplate rating, which is used to calculate capital costs; an average capability rating, which is used to calculate annual energy output; and a summer peak rating, which is used to calculate peak contribution. Operating assumptions include heat rate, which specifies average plant efficiency in units of Btu of fuel used per kWh of electricity generated, and capacity factor, which specifies the percent of annual hours the plant operates at its average capability. Emission assumptions for three key emissions are all specified in pounds of pollutant emitted per Btu of fuel consumed. Emissions factors for Valmont are consistent with its recent historical emissions. Emissions factors for other options are typical for new generating plants, but could vary if alternative emissions control technologies are applied.

Table 3 provides the cost assumptions used to define each repowering option, including capital investment as well as ongoing operations and maintenance (O&M) costs. Where appropriate, capital costs include adjustments for the required demolition of existing infrastructure at the Valmont site. In addition, capital costs for solar options have been adjusted to reflect the investment tax credit. O&M costs include fixed and variable components. For certain renewable options, variable costs include production tax credits for the first ten years

Results

The Appendix provide a full set of analysis results, including, for each option, energy and capacity output, lifecycle costs, levelized costs, and annual emissions. The remainder of this section provides an overview of key results.

Energy and Capacity Output

Figure 1 displays the energy and capacity output calculated for each option. For clarity, the label "Valmont Coal" in Figure 1 denotes all of the options with capacity and energy output that are identical to the Valmont coal option (Valmont coal, Valmont natural gas, 186 MW combined cycle, 186 MW biomass, coal/gas hybrid, coal/solar hybrid). The figure shows, on the Y-axis, the average capability (capacity) for each option, and, on the X-axis, the capacity factor for each option. The area of the rectangle proscribed by each point is proportional to the energy generated from each option. (The areas for key options are highlighted in different shades of blue.)

Table 2
Technical Inputs

	Plant Capacity			Operations		Emissions Factors		
	Name-plate Rating	Average Capability Rating	Summer Peak Rating	Average Heat Rate	Average Capacity Factor	CO_2	SO_x	NO_x
	MW	MW	MW	Btu/ kWh	%/ year	lbs/ MMBtu	lbs/ MMBtu	lbs/ MMBtu
Existing Plant Options								
Valmont Coal	166	186	187	9,946	74%	206	0.1292	0.1292
Valmont Gas	166	186	187	9,946	74%	119	0.0005	0.0005
Repowering Options								
Combined Cycle								
Small, Baseload	186	186	163	6,953	74%	119	0.0005	0.0005
Large, Intermediate	555	555	485	6,953	40%	119	0.0005	0.0005
Large, Baseload	555	555	485	6,953	74%	119	0.0005	0.0005
Photovoltaic								
Small, Fixed Axis	23	23	10	-	22%	-	-	-
Large, Fixed Axis	62	62	28	-	22%	-	-	-
Small, Tracking	23	23	13	-	28%	-	-	-
Large, Tracking	62	62	34	-	28%	-	-	-
Solar Thermal								
Small	19	19	19	-	26%	-	-	-
Large	50	50	50	-	26%	-	-	-
Wind	6	6	1	-	18%	-	-	-
Biomass								
Small	100	100	100	9,749	74%	-	0.0200	0.0200
Large	186	186	187	9,222	74%	-	0.0200	0.0200
Hybrid Repowering Options								
Solar Thermal/Coal	166	186	187	9,712	74%	206	0.1292	0.1292
Solar Thermal/Combined Cycle	530	530	485	6,789	40%	119	0.0005	0.0005
Biomass/Coal	166	186	187	9,946	74%	175	0.1175	0.1175
Biomass/Combined Cycle	370	370	335	7,715	40%	80	0.0068	0.0068

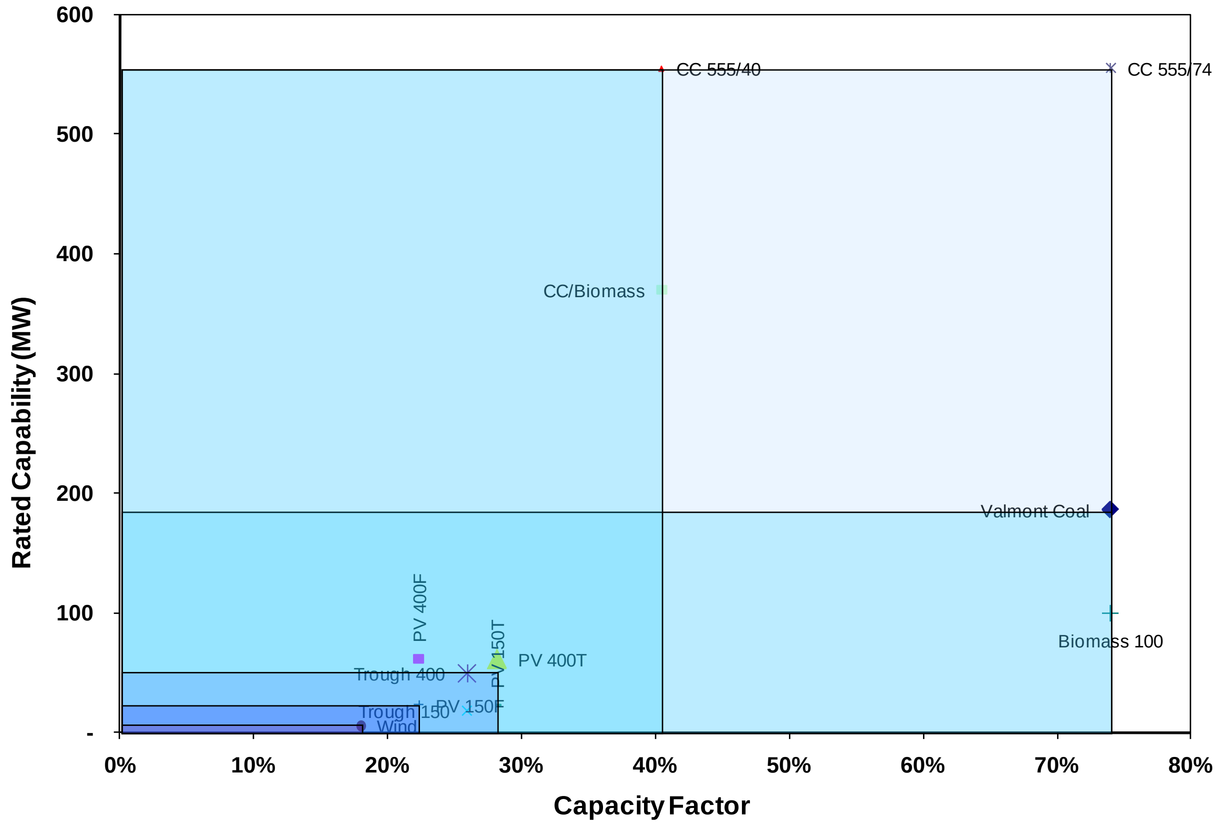
Table 3
Cost Inputs

	Capital Costs		Operating Costs		
	Construction	Valmont Demolition	Fixed O&M	Variable O&M	Production Tax Credit
	$/kW	$/kW	$/kW-year	$/MWh	$/MWh
Existing Plant Options					
Valmont Coal	$0	$0	$ 27.08	$4.06	$0.00
Valmont Gas	$0	$0	$ 35.50	$4.06	$0.00
Repowering Options					
Combined Cycle					
Small, Baseload	$1,063	$0	$ 20.87	$1.74	$0.00
Large, Intermediate	$1,063	$0	$ 20.87	$1.74	$0.00
Large, Baseload	$1,063	$0	$ 20.87	$1.74	$0.00
Photovoltaic					
Small, Fixed Axis	$3,349	$92	$ 5.32	$0.00	$0.00
Large, Fixed Axis	$3,349	$35	$ 5.32	$0.00	$0.00
Small, Tracking	$4,093	$92	$ 38.27	$0.00	$0.00
Large, Tracking	$4,093	$35	$ 38.27	$0.00	$0.00
Solar Thermal					
Small	$3,870	$113	$ 63.78	$1.06	$0.00
Large	$3,498	$43	$ 63.78	$1.06	$0.00
Wind	$2,126	$0	$ 31.89	$0.00	($21.00)
Biomass					
Small	$1,728	$21	$ 34.02	$7.44	($10.00)
Large	$1,607	$0	$ 34.02	$7.44	($10.00)
Hybrid Repowering Options					
Solar Thermal/Coal	$136	$0	$ 29.40	$3.87	$0.00
Solar Thermal/Combined Cycle	$1,047	$0	$ 21.88	$1.73	$0.00
Biomass/Coal	$61	$0	$ 28.12	$4.57	($1.50)
Biomass/Combined Cycle	$1,059	$0	$ 24.17	$3.18	($2.51)

Figure 1 demonstrates that many of the options considered would substantially decrease generation at the Valmont site (and would require make-up power to be purchased from the market). All of the stand-alone solar and wind options decrease energy output by at least 87%. For example, even the solar/wind option with the largest output (PV400T, the photovoltaic tracking system covering 400 acres), produces an average output of 62 MW (a 67% reduction over the existing plant), and an expected capacity factor of 28% (a 62% reduction over the existing plant), for a combined reduction in energy output of over 87%. The option with the smallest energy output (Wind) reduces output at the site by over 99%.

Figure 1 also highlights how the on-site combined cycle options will substantially increase output. The on-site combined cycle plants all have capacity output of 555 MW, or approximately three times the output of the Valmont coal configuration. At a 40% capacity factor, site output increases by 63% compared to the existing coal option; at Valmont's existing 74% capacity factor, energy output also triples.

Figure 1
Output



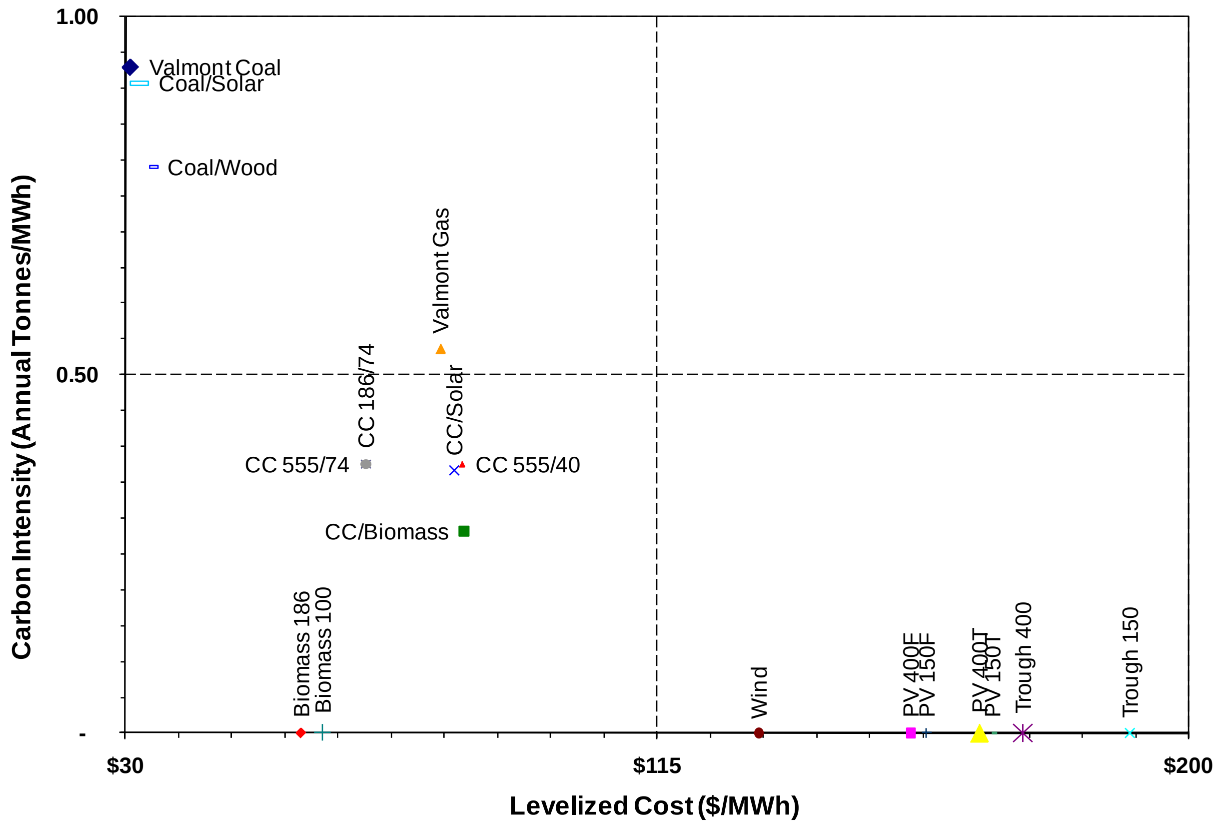
Carbon Emissions

Figure 2 compares carbon emissions to levelized cost for each option. In Figure 2, levelized costs include only on-site costs and exclude costs associated with additional market purchases and sales. (These will be analyzed in more detail in Figure 3.)

Key findings from Figure 2 include:

- The existing Valmont coal option has the highest carbon footprint at 0.92 tonnes/MWh. It also has the lowest unit cost at just over $30/MWh.
- The two coal hybrid options, both of which continue to create the majority of plant output through coal combustion, provide reductions in carbon footprints for relatively modest costs increases. The coal/wood hybrid produces larger carbon savings for slightly higher costs.
- The two biomass options both eliminate carbon emissions, at unit costs of around $60/MWh.

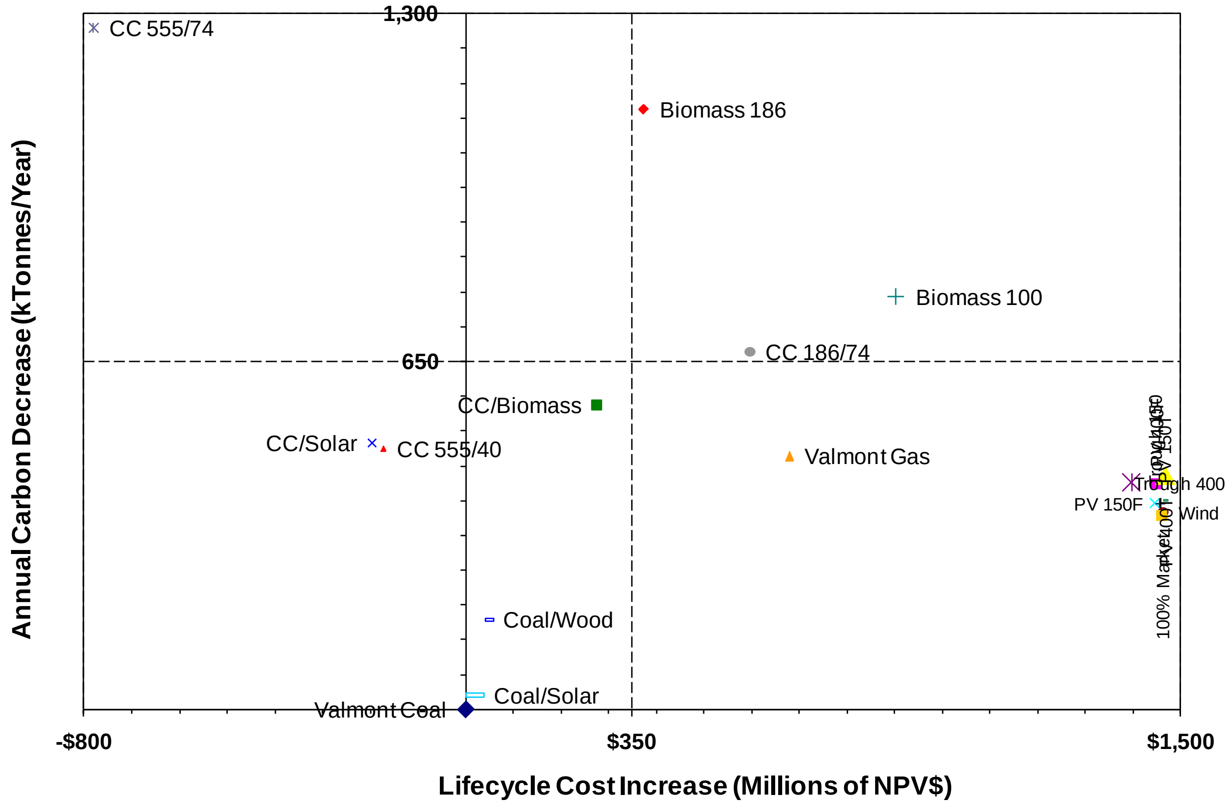
Figure 2
Carbon Emission per MWh vs. Levelized Cost per MWh



- The various natural gas options lower carbon emissions to between 28 and 54 tonnes/MWh, at costs between $68 and $84/MWh. The gas steam option provides the smallest carbon reduction (just over 40%), at a cost of around $80/MWh. The combined cycle options—which are more efficient than the steam option, but require additional capital investment—each reduce carbon emissions by just under 60%. The hybrid combined cycle options further reduce carbon emissions (proportional to the output provided by renewable supplementation), with larger savings for the biomass hybrid.
- The stand-alone renewable options all eliminate carbon emissions for much higher costs. The wind option has the lowest unit costs from this group at $131/MWh. The various stand-alone solar options have unit costs between $158/MWh and $191/MWh.

Figure 3 compares lifecycle costs and annual carbon emissions for each option. Lifecycle costs and emissions include on-site operation, as well as impacts from market power purchases and sales. For ease of comparison, Figure 3 shows costs and emissions relative to those for the existing Valmont coal option. (That is, the X-axis of Figure 3 shows costs increases relative to Valmont; the Y-axis shows decreases in annual carbon emissions.)

Figure 3
Carbon Emissions and Costs Compared to Existing Valmont Option



Key findings from Figure 3 include:

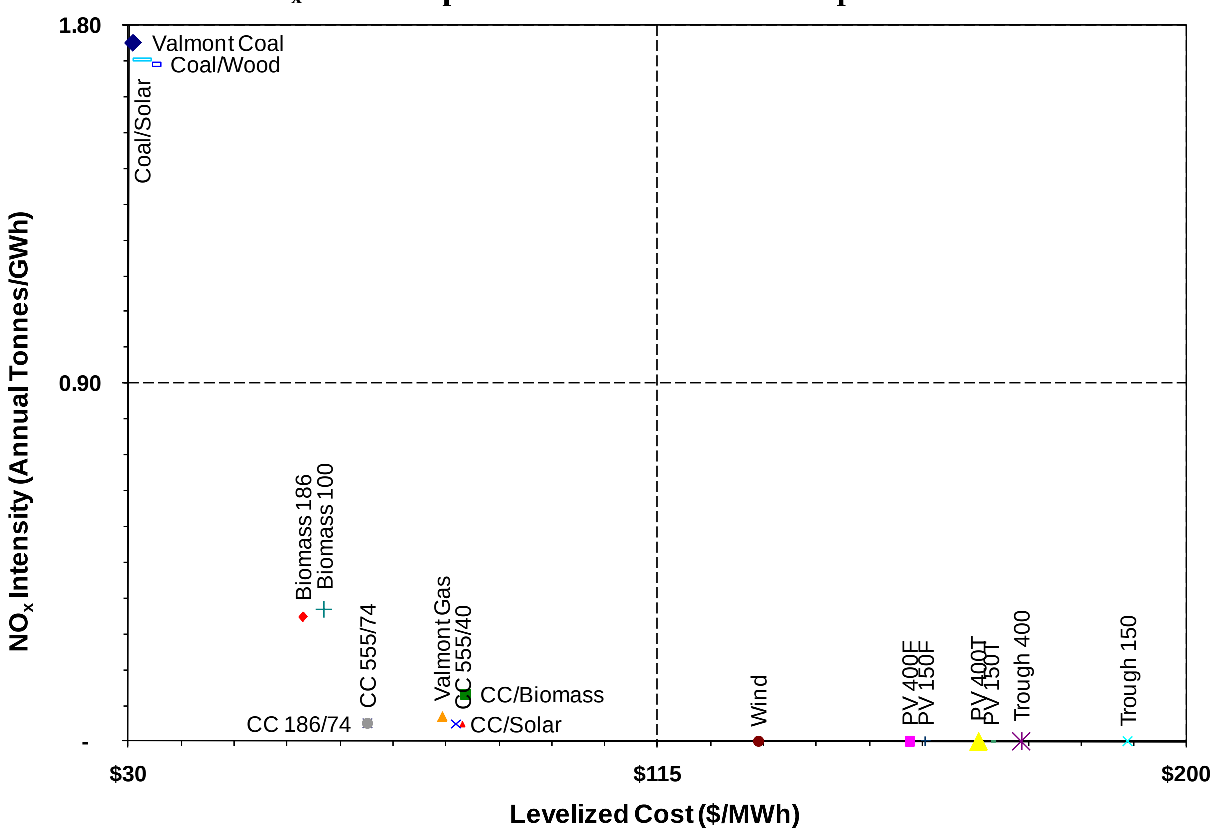
- As shown in Figure 2, the two coal hybrid options create carbon savings for relatively small cost increases. The coal/wood hybrid produces larger carbon savings for slightly higher costs.
- The on-site combined cycle options all decrease total carbon emissions and also decrease costs relative to the existing Valmont plant. The combined cycle options lower carbon emissions by reducing on-site coal emissions, but also by displacing relatively high carbon emissions elsewhere in the western power market through market sales. The combined cycle options are able to lower costs because the excess revenue Xcel would achieve from market sales would more than offset Xcel's construction investments in the plants.
- Compared to the stand-alone combined cycle option (at 40% capacity factor), the combined cycle/solar hybrid lowers both emissions and costs, indicating that it could be a preferred option. Emissions savings come from the zero-emission output associated with the solar contribution. Cost savings are created because the solar system can rely on the steam and turbine systems already required for the combined cycle unit, lowering the costs of the solar system.
- The combined cycle/biomass option provides additional carbon savings, for substantially higher costs.

- The 186 MW biomass option lowers carbon emissions by over 1,100 thousand tonnes per year, at a cost increase of around $374 million. The 100 MW biomass option creates less carbon savings (in proportion to its capacity) and incurs higher lifecycle costs, because it must rely on expensive, carbon intensive replacement power to make up shortfalls compared to the current Valmont coal plant.
- The 186 MW combined cycle option has higher cost and higher carbon emissions than the 186 MW biomass option.
- The stand-alone solar and wind options all cluster around a point providing approximately 330 tonnes per year of carbon reductions at a cost of approximately $1.5 billion. Since these options only replace between 1% and 13% of Valmont's existing output, their results are dominated by the costs and carbon footprint of the replacement power required to make up the shortfall. Carbon reductions come about more from the natural gas purchases included in the replacement power than they do from the on-site renewable generation technologies themselves.

NO_x Emissions

Figure 4 compares NO_x emissions to levelized costs for each option. Levelized costs are the same as those shown in Figure 2 (and, again, include only on-site costs).

Figure 4
NO_x Emission per MWh vs. Levelized Cost per MWh



In general, the pattern of is similar to the carbon results shown in Figure 2, i.e.:

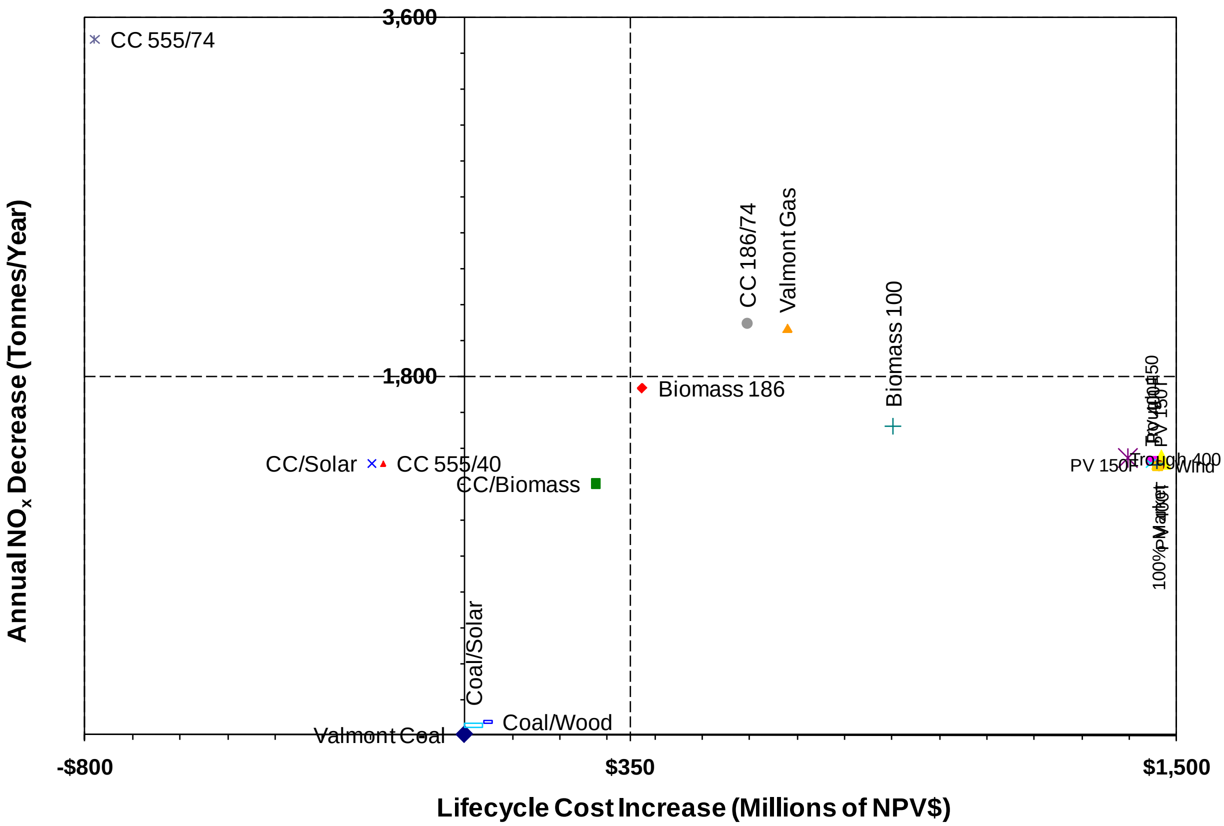
- The existing Valmont coal configuration has the highest emissions and the lowest unit costs.
- The coal hybrid options produce modest emissions reductions for modest cost increases.
- The stand-alone solar and wind options eliminate emissions, but come at high costs.

Key differences from the unitized carbon emissions shown in Figure 2 include:

- While the biomass options have zero carbon footprint, they do not eliminate NO_x reductions (although they continue to produce large reductions).
- The natural gas options have lower NO_x intensity than the biomass options.

Figure 5 compares lifecycle costs and NO_x emissions for each option. Similar to Figure 3, costs and emissions include impacts of market purchases and sales, and are shown relative to those for the existing Valmont coal option.

Figure 5
NO_x Emissions and Costs Compared to Existing Valmont Option



Again, in general, the pattern of costs and emissions changes is similar to the carbon results shown in Figure 3. The key differences are driven by the difference in emission reductions for biomass (which has lower NO_x reductions, compared to carbon) and natural gas (which has higher NO_x reductions, compared to carbon). As a result:

- The coal/wood hybrid produces much lower NO_x benefits.
- The 186 MW combined cycle option produces higher NO_x benefits than the 186 MW biomass plant.

Otherwise, key findings from the carbon analysis show parallels in the NO_x evaluation, i.e.:

- The on-site combined cycle options produce large emissions reductions for costs below that of the existing coal option.
- The combined cycle/solar option lowers both emissions and costs compared to the stand-alone combined cycle option.
- The stand-alone solar and wind options have costs and emissions profiles that are dominated by the large need for replacement power in these scenarios.

Carbon Price Sensitivity Analysis

Figure 6 shows the same comparison shown in Figure 3 (i.e., carbon emissions reduction and cost increases relative to the existing Valmont coal option), under the assumption that a price is put on future carbon emissions (through a carbon tax or a cap-and-trade system). Carbon price assumptions are consistent with estimates that the USEPA provided to Congress analyzing the impacts of proposed climate change legislation.

The carbon reductions for each option are identical to that shown in Figure 3, while costs have shifted "to the left," indicating that, in the carbon-tax sensitivity case, the cost premium relative to the existing Valmont coal option goes down for every option. (Note that the scale for the X-axis of Figure 6 is expanded dramatically from that in Figure 3: -$1.4 billion to +$1.4 billion in Figure 6, compared to -$800 million to +$1.5 billion in Figure 3.)

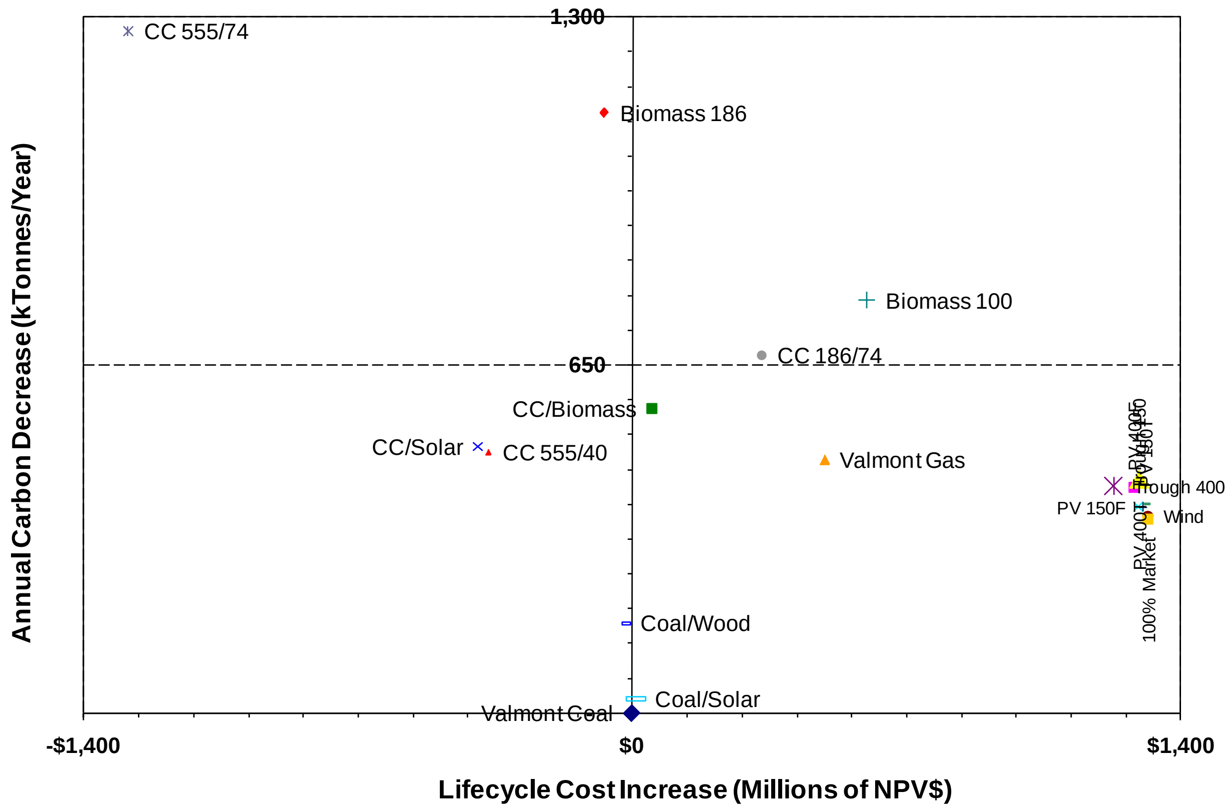
In general, the pattern of emission decreases and cost increases with carbon tax is similar to that shown in Figure 3 for the scenarios without the carbon tax. That is, while the carbon tax lowers the cost premium associated with carbon reductions for all options, the options themselves produce the same general ranking in terms of costs.

The key difference to this general observation relates to the biomass options. In the carbon tax sensitivity case, the 186 MW biomass option, as well as the coal/wood hybrid option, are both cheaper than the existing Valmont coal option.

Note that the carbon tax scenario adds costs to the Valmont Coal scenario that more than double the fuel costs associated with the plant. The carbon taxes have a less dramatic affect on the natural gas options, with an increase in on-site fuel costs of approximately 25%. In addition, the impact of carbon taxes on the larger on-site combined cycle options is more complicated, since the market sales associated with these options are also substantially affected by the carbon taxes.

We also note that additional sensitivity analysis testing higher fuel and carbon prices produces similar results, that is, while changes in fuel and carbon prices affected the overall cost premiums associated with the different options, the options themselves produce the same general rankings in terms of costs.

Figure 6
Carbon Emissions and Costs Compared to Existing Valmont Option
Carbon Tax Scenario



Conclusions

We reach the following conclusions from the analysis:

<u>Overall</u>

- A number of viable options exist for repowering the Valmont site in a manner that reduces overall carbon and NO_x emissions.
- The most attractive renewable options for the site include:
  - Stand-alone biomass options;
  - Hybrid coal/wood options involving retrofitting burners in the existing coal configuration to burn high-quality wood fuel; and
  - Hybrid fossil/solar thermal options tied to either the existing coal configuration or to a new combined cycle plant constructed at the site.
- Replacing the existing Valmont output with output from natural gas combined cycle plants—either new plants constructed at the Valmont site, or a portion of a larger plant constructed elsewhere—can also produce substantial emissions reductions.
- Stand-alone solar and wind options will greatly reduce output at the site. While these options would eliminate site emissions, they would also require large amounts of power purchased elsewhere on the system to replace the historic Valmont output. These replacement purchases would have large costs and high emissions associated with them.

Stand-Alone Biomass

- Renewable options with the largest potential for emissions reductions involve biomass.
- Per MWh of electricity generated, compared to the existing Valmont coal plant, stand-alone biomass options reduce net carbon emissions by 100% and NO_x emissions by 80% to 90%.
- Given potential constraints in available fuel supply, it is unclear how large a biomass plant could be supported at the Valmont site. Additional research should be pursued to better define the long-term availability and costs for local biomass fuels.
- If a carbon tax is imposed in the future, construction of a large biomass plant (assuming it could be supported by available fuel supply) would eliminate carbon emissions for costs less than those incurred by operating the existing coal configuration.
- Without a carbon tax, a large biomass plant would be more expensive than the existing coal configuration. However, without a carbon tax, a large biomass plant is likely to be less costly than a similar sized combined cycle plant (that is, biomass is cheaper than combined cycle when the impacts of market sales are removed).
- Biomass options present a number of additional challenges, including fuel transportation/traffic issues, uncertainty over net carbon emission reductions, additional air emissions, and other factors.

Hybrid Coal/Wood

- While producing smaller carbon and NO_x emissions reductions than stand-alone options, a hybrid coal/wood option might be an attractive alternative for the Valmont site.
- The hybrid option can be retrofit to the existing plant, allowing Xcel and its customers to fully utilize the remaining useful life of current plant investments.
- If available fuel supply severely limits the stand-alone biomass capacity that can be achieved at the site, the hybrid option could be the most cost-effective approach for maximizing carbon reduction at the site. That is, if fuel supply constraints limit biomass capacity to less than approximately 50 MW, it might be more prudent to invest in the hybrid retrofit than it would be to replace the existing plant.
- Per MWh generated, the technology used to generate electricity in the hybrid scenario is as effective as the biomass stand-alone technologies at reducing carbon; however due to its high combustion temperatures, the hybrid option is not as effective at reducing NO_x emissions.
- A hybrid coal/wood option would also face the additional challenges listed previously for the biomass stand-alone options (e.g., fuel transportation/traffic issues, uncertainty over net carbon emission reductions, additional air emissions, etc).

Hybrid Solar

- A hybrid solar thermal system configured with either the existing coal plant or a new combined cycle plant can produce small, but economic carbon and NO_x reductions.
- By leveraging infrastructure needed for the fossil plants, the hybrid solar system can avoid the costs associated with certain steam and turbine systems, greatly increasing its cost-effectiveness.
- The benefits of the hybrid solar system are limited by the land available at the site for solar collectors.

Stand-Alone Solar and Wind

- While stand-alone solar and wind options for the site are also viable, limitations on available land severely limit the energy that can be generated by these options, reducing their attractiveness as repowering options.
- All of the stand-alone wind and solar options evaluated reduced site energy output by at least 87%, triggering the need for large replacement power purchases.
- The relative expense and carbon intensity of replacement power severely limits the benefits that can be provided by stand-alone solar and wind alternatives.

Combined Cycle

- On-site combined cycle options could greatly increase electricity output at the Valmont site.
    - Typical combined cycle designs leveraging existing infrastructure, such as the existing steam boiler, would approximately triple Valmont capacity.
    - If Xcel operated an on-site combined cycle plant at Valmont's existing 74% capacity factor, energy output would also triple. If Xcel operated at the 40% capacity factor more common for existing combined cycle units, site energy output would increase by 63%.
- Because a new combined cycle plant is likely to be more efficient and lower in carbon intensity than the overall western electric market, the market sales associated with the excess output would create cost and emissions savings that more than offset the increase in on-site output. That is, a large combined cycle plant at the site is likely to have both lower overall emissions and lower overall costs than the existing Valmont coal option.
- Xcel might choose to replace Valmont's output with a portion of a large combined cycle plant constructed elsewhere. An exact replacement of Valmont's coal output with a portion of a new combined cycle plant (the 186 MW combined cycle option) would reduce carbon emissions by around two-thirds and NO_x emissions by almost two-thirds, but come at a lifecycle cost of almost $600 million.
    - This combined cycle investment would be more attractive than simply fueling the existing Valmont plant with natural gas. The combined cycle approach would produce greater carbon and NO_x reductions at much lower costs.
    - This combined cycle investment would be generally less attractive than a comparable investment in on-site biomass (that is, a 186 MW biomass plant). The biomass investment would result in lower lifecycle costs and lower annual carbon emissions, although it would also create a small increase in annual NO_x emissions.

Appendix
Detailed Analysis Results

On-Site Output and Requirements for Market Purchases/Sales from Valmont Repowering Options

	Plant Output			Requirement for Market Purchases/(Market Sales)	
	Average Capability (MW)	Energy (GWh)	Summer Capacity (MW)	Energy (GWh)	Summer Capacity (MW)
Existing Plant Options					
Valmont Coal	186	296	187	-	-
Valmont Gas	186	296	187	-	-
Repowering Options					
Combined Cycle					
Small, Baseload	186	296	163	-	24
Large, Intermediate	555	-	485	296	(298)
Large, Baseload	555	885	485	(588)	(298)
Photovoltaic					
Small, Fixed Axis	23	4	10	292	177
Large, Fixed Axis	62	11	28	286	159
Small, Tracking	23	4	13	292	174
Large, Tracking	62	11	34	286	153
Solar Thermal					
Small	19	6	19	291	168
Large	50	15	50	281	137
Wind	6	3	1	294	186
Biomass					
Small	100	159	100	137	87
Large	186	296	187	-	-
Hybrid Repowering Options					
Solar Thermal/Coal	186	296	187	-	-
Solar Thermal/Combined Cycle	530	-	335	296	(148)
Biomass/Coal	186	296	187	-	-
Biomass/Combined Cycle	370	-	485	296	(298)

Lifecycle Costs Associated with Valmont Repowering Options
(Millions of NPV$)

	Plant Costs								Replacement Power Costs (Revenue)						Total Cost	
	Capital	Fuel	Carbon Tax	Sulfur Tax	Fixed O&M	Variable O&M	PTC Tax Credit	Subtotal	Energy	Capacity	Trans-mission	Carbon Tax	Sulfur Tax	Subtotal	Total	Increase from Valmont
Existing Plant Options																
Valmont Coal	$0	$282	$0	$0	$72	$70	$0	$424	$0	$0	$0	$0	$0	$0	$424	$0
Valmont Gas	$0	$939	$0	$0	$94	$70	$0	$1,103	$0	$0	$0	$0	$0	$0	$1,103	$679
Repowering Options																
Combined Cycle																
Small, Baseload	$198	$657	$0	$0	$55	$30	$0	$939	$0	$80	$0	$0	$0	$80	$1,019	$595
Large, Intermediate	$590	$1,071	$0	$0	$165	$49	$0	$1,874	-$995	-$968	$339	$0	$0	-$1,624	$250	-$173
Large, Baseload	$590	$1,959	$0	$0	$165	$89	$0	$2,803	-$2,531	-$968	$339	$0	$0	-$3,160	-$357	-$780
Photovoltaic																
Small, Fixed Axis	$79	$0	$0	$0	$2	$0	$0	$81	$1,225	$574	$0	$0	$0	$1,799	$1,880	$1,456
Large, Fixed Axis	$208	$0	$0	$0	$5	$0	$0	$213	$1,140	$518	$0	$0	$0	$1,658	$1,871	$1,447
Small, Tracking	$97	$0	$0	$0	$13	$0	$0	$109	$1,212	$566	$0	$0	$0	$1,778	$1,887	$1,464
Large, Tracking	$254	$0	$0	$0	$34	$0	$0	$288	$1,105	$498	$0	$0	$0	$1,602	$1,890	$1,467
Solar Thermal																
Small	$75	$0	$0	$0	$17	$1	$0	$92	$1,229	$547	$0	$0	$0	$1,776	$1,868	$1,444
Large	$177	$0	$0	$0	$45	$2	$0	$224	$1,151	$445	$0	$0	$0	$1,596	$1,820	$1,397
Wind	$13	$0	$0	$0	$3	$0	-$1	$14	$1,266	$606	$0	$0	$0	$1,872	$1,886	$1,462
Biomass																
Small	$175	$206	$0	$0	$48	$69	-$44	$454	$590	$283	$0	$0	$0	$873	$1,327	$903
Large	$299	$362	$0	$0	$90	$128	-$81	$797	$0	$0	$0	$0	$0	$0	$797	$374
Hybrid Repowering Options																
Solar Thermal/Coal	$23	$276	$0	$0	$78	$66	$0	$442	$0	$0	$0	$0	$0	$0	$442	$19
Solar Thermal/Combined Cycle	$392	$699	$0	$0	$127	$59	-$22	$1,255	-$238	-$481	$163	$0	$0	-$557	$699	$275
Biomass/Coal	$10	$313	$0	$0	$74	$78	-$12	$464	$0	$0	$0	$0	$0	$0	$464	$40
Biomass/Combined Cycle	$555	$999	$0	$0	$165	$46	$0	$1,765	-$893	-$968	$324	$0	$0	-$1,537	$228	-$196
Market Purchases																
100% Market Purchases	$0	$0	$0	$0	$0	$0	$0	$0	$1,276	$608	$0	$0	$0	$1,883	$1,883	$1,460

Levelized Costs Associated with Valmont Repowering Options
($/MWh of On-Site Plant Output)

	Plant Costs							
	Capital	Fuel	Carbon Tax	Sulfur Tax	Fixed O&M	Variable O&M	PTC Tax Credit	Subtotal
Existing Plant Options								
Valmont Coal	$0	$21	$0	$0	$5	$5	$0	$31
Valmont Gas	$0	$68	$0	$0	$7	$5	$0	$80
Repowering Options								
Combined Cycle								
Small, Baseload	$14	$48	$0	$0	$4	$2	$0	$68
Large, Intermediate	$26	$48	$0	$0	$7	$2	$0	$84
Large, Baseload	$14	$48	$0	$0	$4	$2	$0	$68
Photovoltaic								
Small, Fixed Axis	$155	$0	$0	$0	$3	$0	$0	$158
Large, Fixed Axis	$152	$0	$0	$0	$3	$0	$0	$155
Small, Tracking	$149	$0	$0	$0	$19	$0	$0	$169
Large, Tracking	$147	$0	$0	$0	$19	$0	$0	$166
Solar Thermal								
Small	$154	$0	$0	$0	$35	$1	$0	$191
Large	$137	$0	$0	$0	$35	$1	$0	$173
Wind	$118	$0	$0	$0	$25	$0	-$12	$131
Biomass								
Small	$24	$28	$0	$0	$7	$9	-$6	$62
Large	$22	$26	$0	$0	$7	$9	-$6	$58
Hybrid Repowering Options								
Solar Thermal/Coal	$2	$20	$0	$0	$6	$5	$0	$32
Solar Thermal/Combined Cycle	$26	$47	$0	$0	$9	$4	-$1	$84
Biomass/Coal	$1	$23	$0	$0	$5	$6	-$1	$34
Biomass/Combined Cycle	$26	$47	$0	$0	$8	$2	$0	$83
Market Purchases								
100% Market Purchases	$0	$0	$0	$0	$0	$0	$0	$0

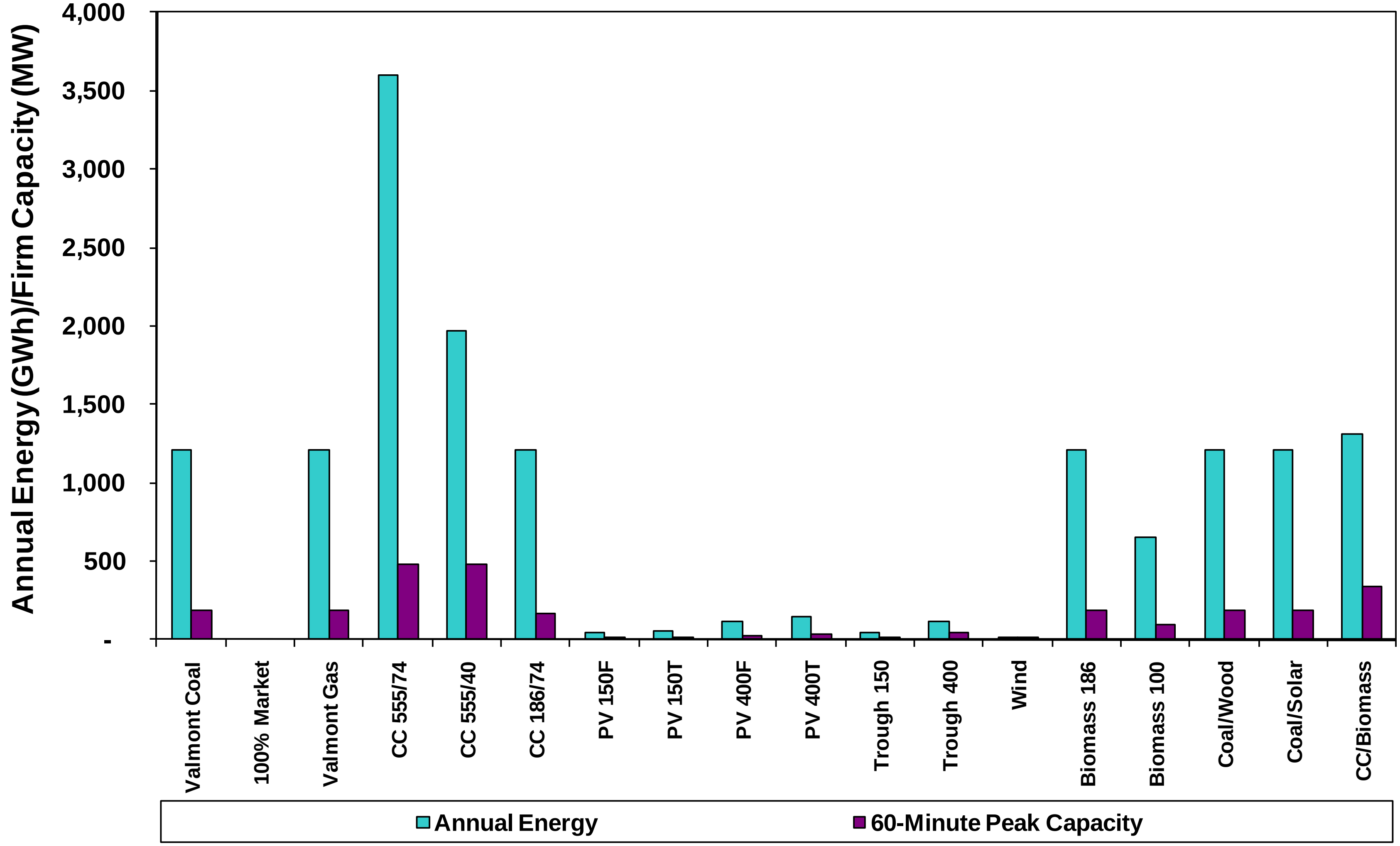
Levelized Costs Associated with Valmont Repowering Options
($/MWh of Valmont Coal Plant Output)

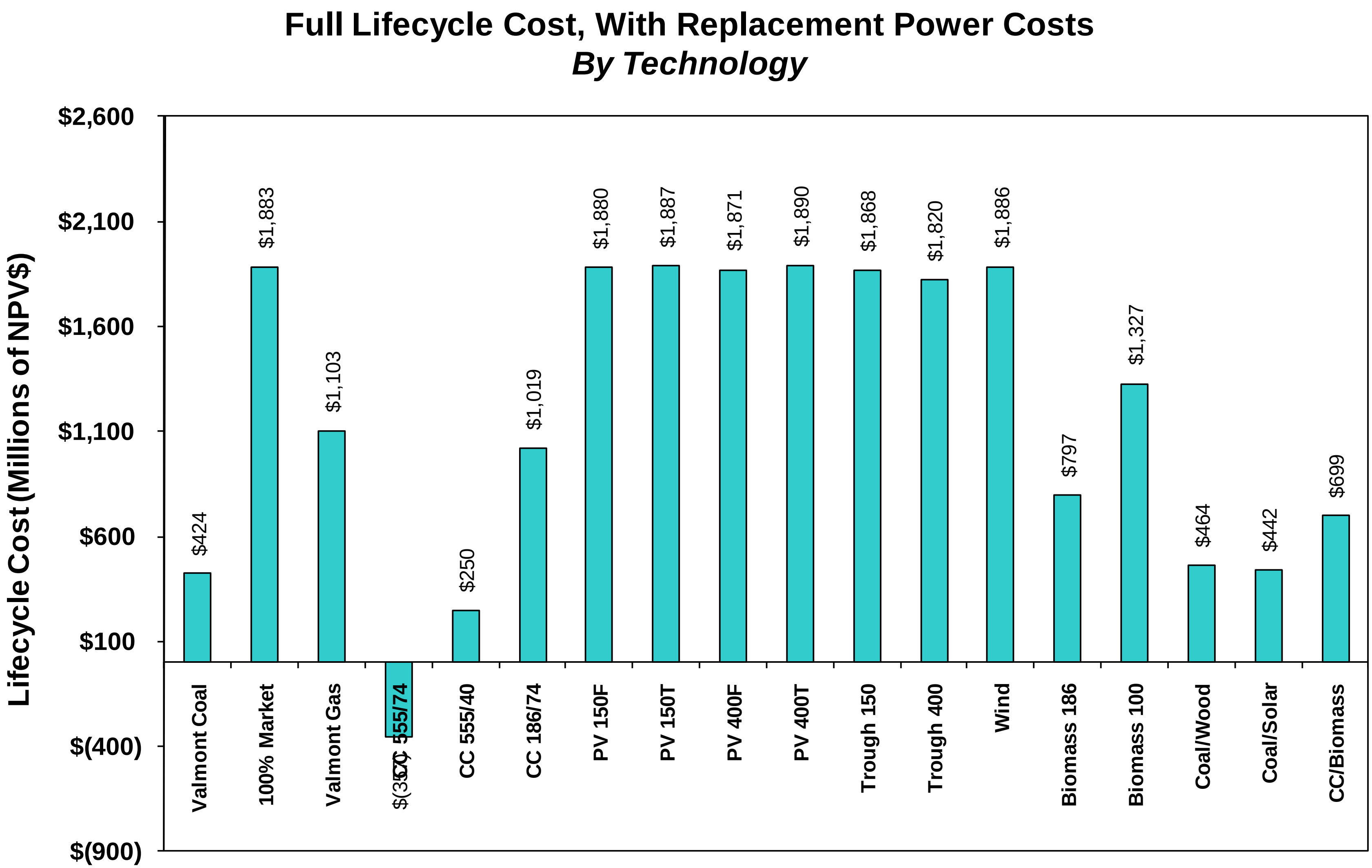
	On-Site Costs								Replacement Power Costs						Total Cost	
	Capital	Fuel	Carbon Tax	Sulfur Tax	Fixed O&M	Variable O&M	PTC Tax Credit	Subtotal	Energy	Capacity	Trans-mission	Carbon Tax	Sulfur Tax	Subtotal	Total	Increase from Valmont
Existing Plant Options																
Valmont Coal	$0	$21	$0	$0	$5	$5	$0	$31	$0	$0	$0	$0	$0	$0	$31	$0
Valmont Gas	$0	$68	$0	$0	$7	$5	$0	$80	$0	$0	$0	$0	$0	$0	$80	$49
Repowering Options																
Combined Cycle																
Small, Baseload	$14	$48	$0	$0	$4	$2	$0	$68	$0	$6	$0	$0	$0	$6	$74	$43
Large, Intermediate	$43	$78	$0	$0	$12	$4	$0	$137	-$72	-$71	$25	$0	$0	-$118	$18	-$13
Large, Baseload	$43	$143	$0	$0	$12	$6	$0	$204	-$184	-$71	$25	$0	$0	-$230	-$26	-$57
Photovoltaic																
Small, Fixed Axis	$6	$0	$0	$0	$0	$0	$0	$6	$89	$42	$0	$0	$0	$131	$137	$106
Large, Fixed Axis	$15	$0	$0	$0	$0	$0	$0	$16	$83	$38	$0	$0	$0	$121	$136	$105
Small, Tracking	$7	$0	$0	$0	$1	$0	$0	$8	$88	$41	$0	$0	$0	$130	$137	$107
Large, Tracking	$19	$0	$0	$0	$2	$0	$0	$21	$80	$36	$0	$0	$0	$117	$138	$107
Solar Thermal																
Small	$5	$0	$0	$0	$1	$0	$0	$7	$90	$40	$0	$0	$0	$129	$136	$105
Large	$13	$0	$0	$0	$3	$0	$0	$16	$84	$32	$0	$0	$0	$116	$133	$102
Wind	$1	$0	$0	$0	$0	$0	$0	$1	$92	$44	$0	$0	$0	$136	$137	$106
Biomass																
Small	$13	$15	$0	$0	$4	$5	-$3	$33	$43	$21	$0	$0	$0	$64	$97	$66
Large	$22	$26	$0	$0	$7	$9	-$6	$58	$0	$0	$0	$0	$0	$0	$58	$27
Hybrid Repowering Options																
Solar Thermal/Coal	$2	$20	$0	$0	$6	$5	$0	$32	$0	$0	$0	$0	$0	$0	$32	$1
Solar Thermal/Combined Cycle	$29	$51	$0	$0	$9	$4	-$2	$91	-$17	-$35	$12	$0	$0	-$41	$51	$20
Biomass/Coal	$1	$23	$0	$0	$5	$6	-$1	$34	$0	$0	$0	$0	$0	$0	$34	$3
Biomass/Combined Cycle	$40	$73	$0	$0	$12	$3	$0	$129	-$65	-$71	$24	$0	$0	-$112	$17	-$14
Market Purchases																
100% Market Purchases	$0	$0	$0	$0	$0	$0	$0	$0	$93	$44	$0	$0	$0	$137	$137	$106

Air Emissions Associated with Valmont Repowering Options
(Metric Tonnes per Year)

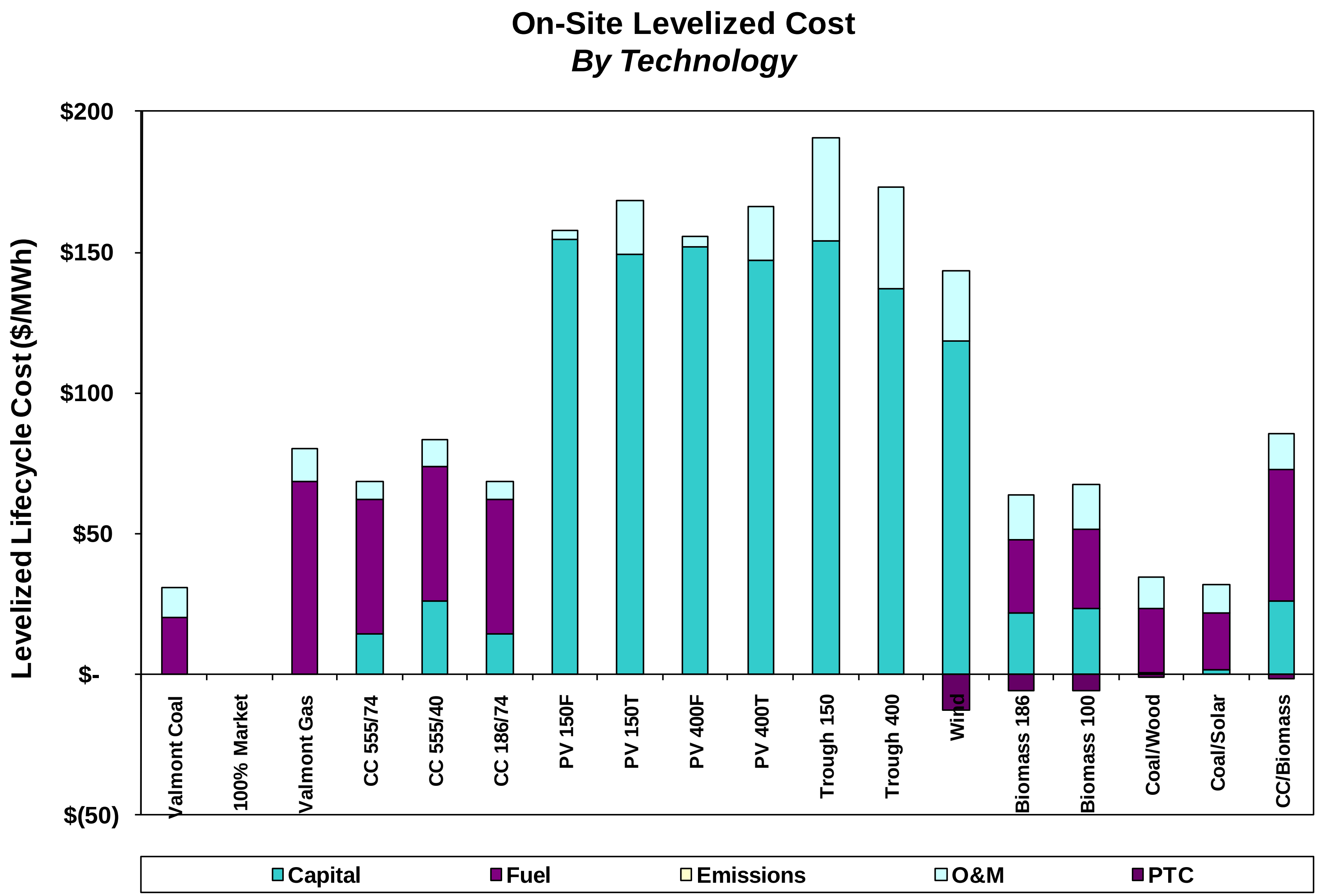
	On-Site Emissions			Total Emissions, Including Incresae/(Reductions) from Market Sales/Purchases		
	CO2	NOx	SOx	CO2	NOx	SOx
Existing Plant Options						
Valmont Coal	1,120,356	703	2,117	1,120,356	703	2,117
Valmont Gas	647,196	3	76	647,196	3	76
Repowering Options						
Combined Cycle						
Small, Baseload	452,438	2	53	452,438	2	53
Large, Intermediate	737,882	3	86	633,694	243	756
Large, Baseload	1,350,018	6	158	(153,041)	(478)	(1,370)
Photovoltaic						
Small, Fixed Axis	-	-	-	735,490	241	760
Large, Fixed Axis	-	-	-	698,575	236	742
Small, Tracking	-	-	-	729,869	240	757
Large, Tracking	-	-	-	683,587	234	736
Solar Thermal						
Small	-	-	-	734,711	239	754
Large	-	-	-	696,496	231	728
Wind	-	-	-	751,540	242	764
Biomass						
Small	-	57	215	350,306	170	571
Large	-	101	378	-	101	378
Hybrid Repowering Options						
Solar Thermal/Coal	1,093,997	686	2,067	1,093,997	686	2,067
Solar Thermal/Combined Cycle	368,962	31	155	552,049	273	858
Biomass/Coal	952,302	639	2,051	952,302	639	2,051
Biomass/Combined Cycle	688,058	3	81	622,691	243	755
Market Purchases						
100% Market Purchases	-	-	-	757,639	244	770

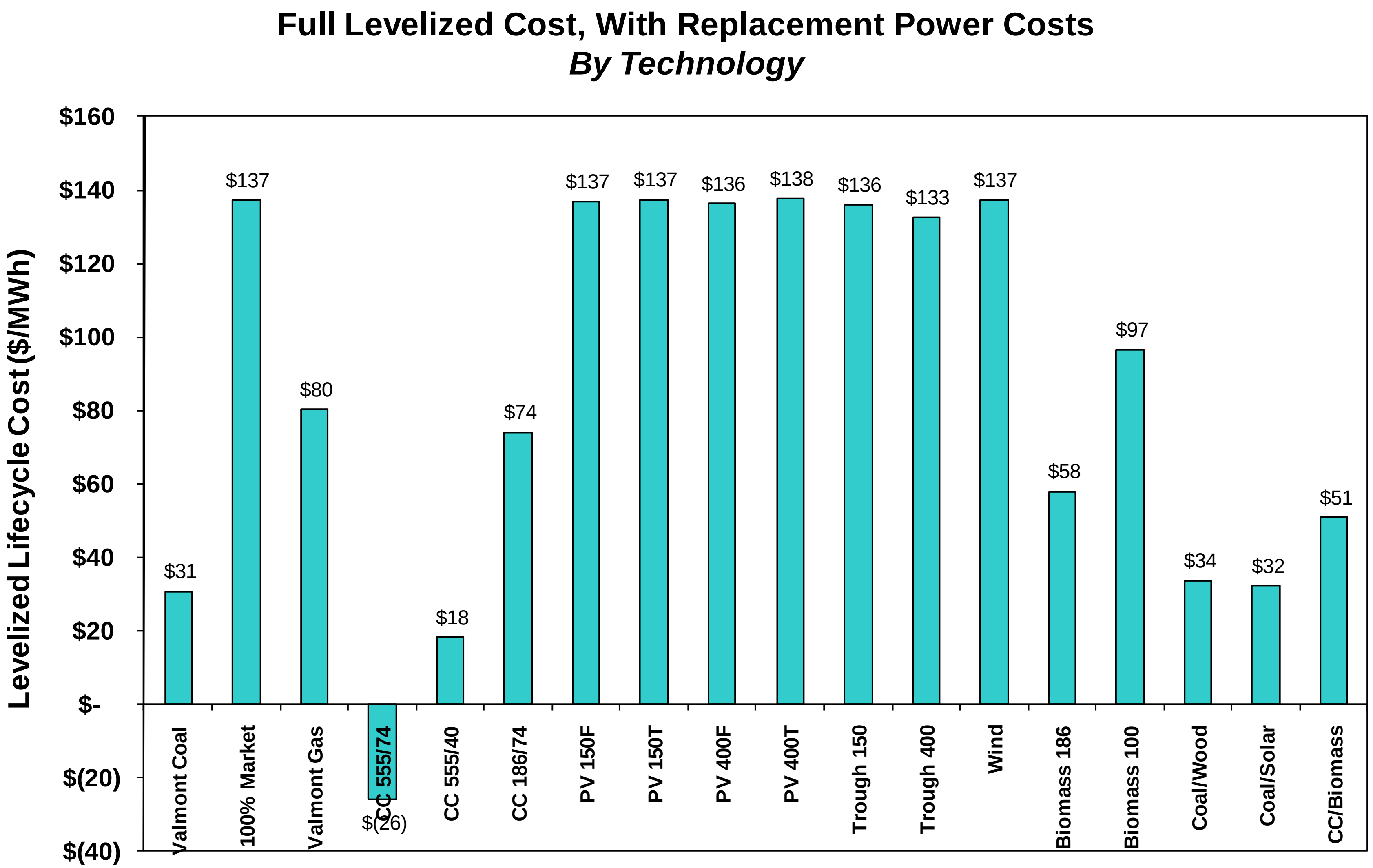
On-Site Plant Output



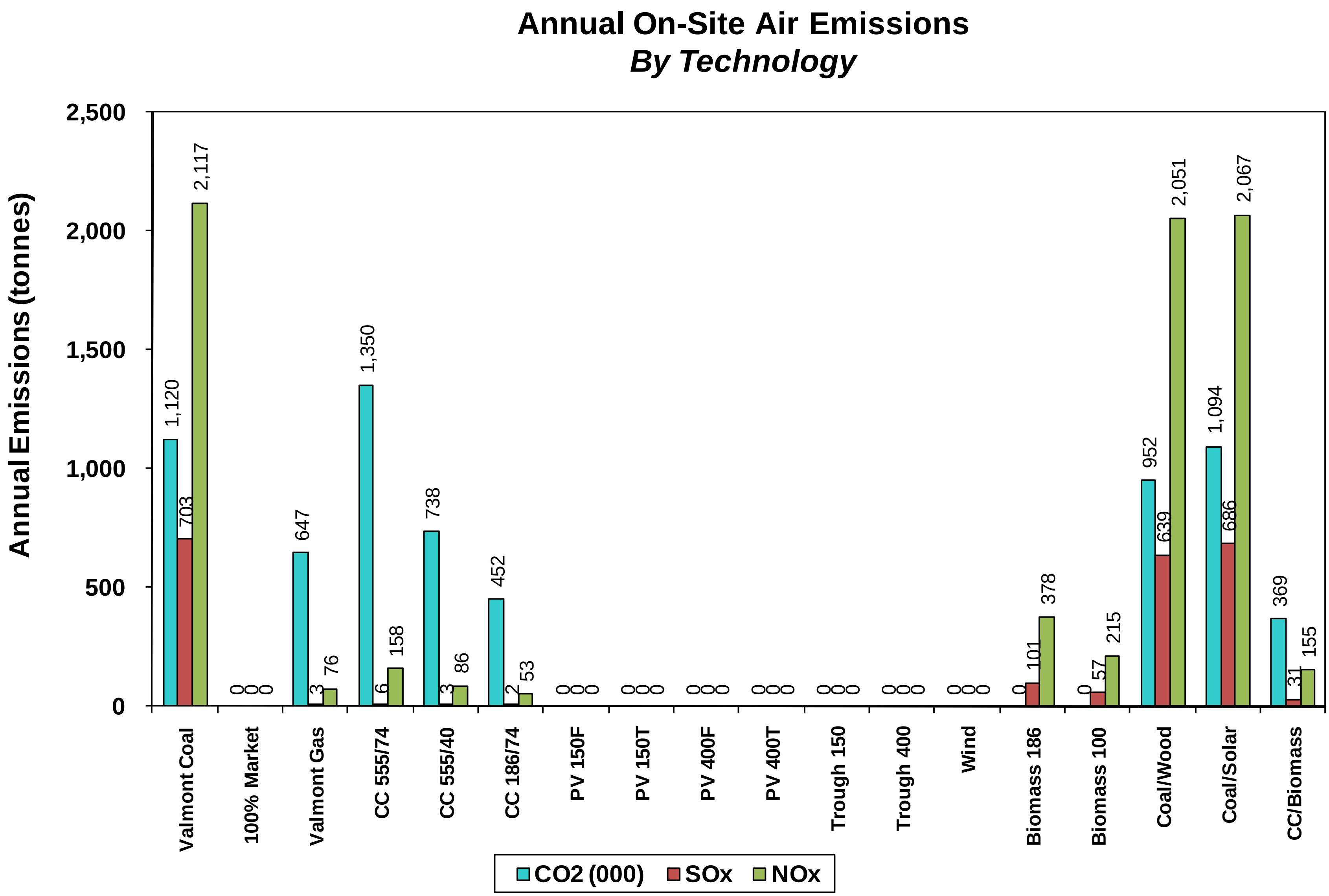


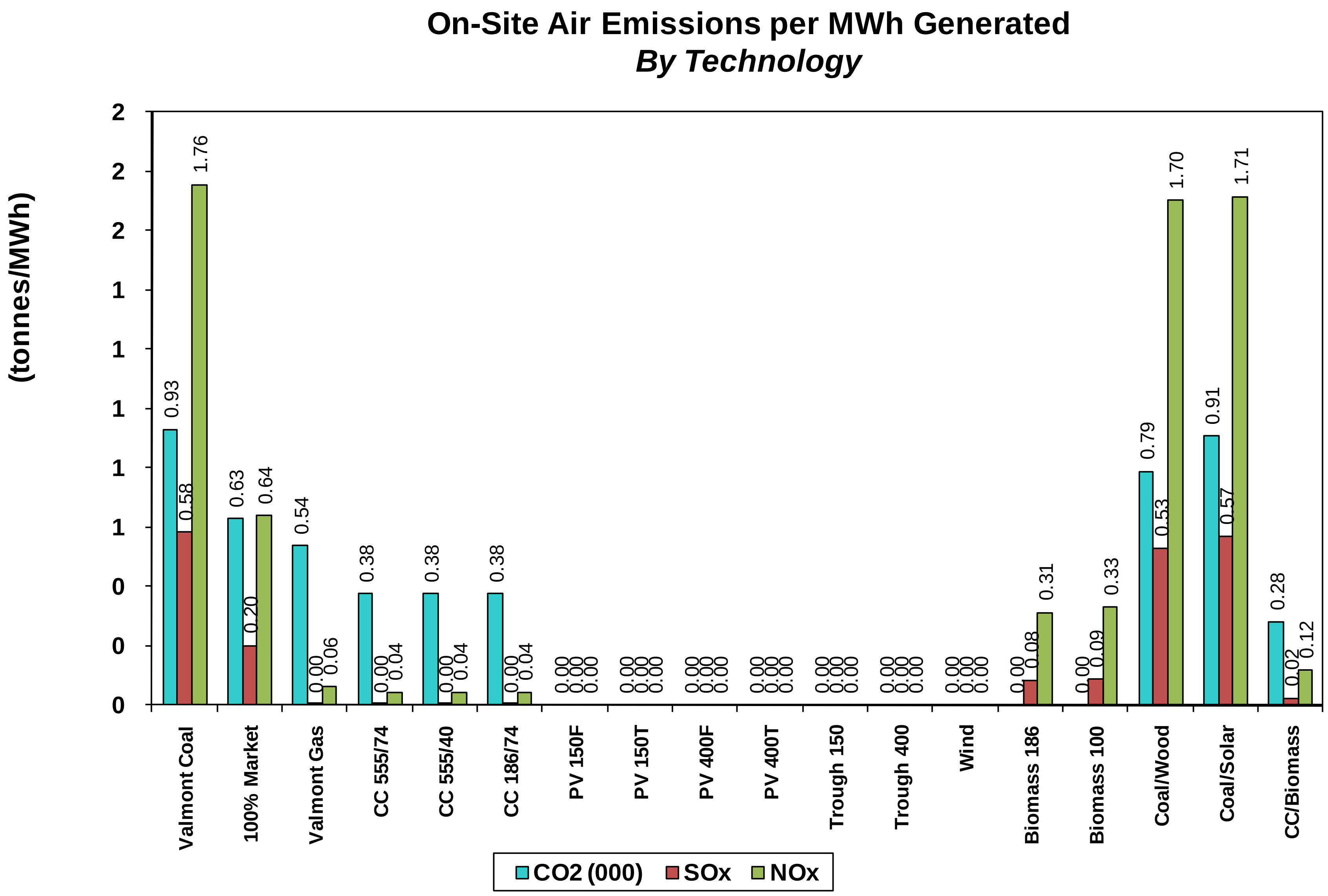
Full Lifecycle Cost, With Replacement Power Costs
By Technology
Lifecycle Cost (Millions of NPV$)
$2,600
$2,100
$1,600
$1,100
$600
$100
$(400)
$(900)
$424
$1,883
$1,103
$(357)
$250
$1,019
$1,880
$1,887
$1,871
$1,890
$1,868
$1,820
$1,886
$797
$1,327
$464
$442
$699
Valmont Coal
100% Market
Valmont Gas
CC 555/74
CC 555/40
CC 186/74
PV 150F
PV 150T
PV 400F
PV 400T
Trough 150
Trough 400
Wind
Biomass 186
Biomass 100
Coal/Wood
Coal/Solar
CC/Biomass

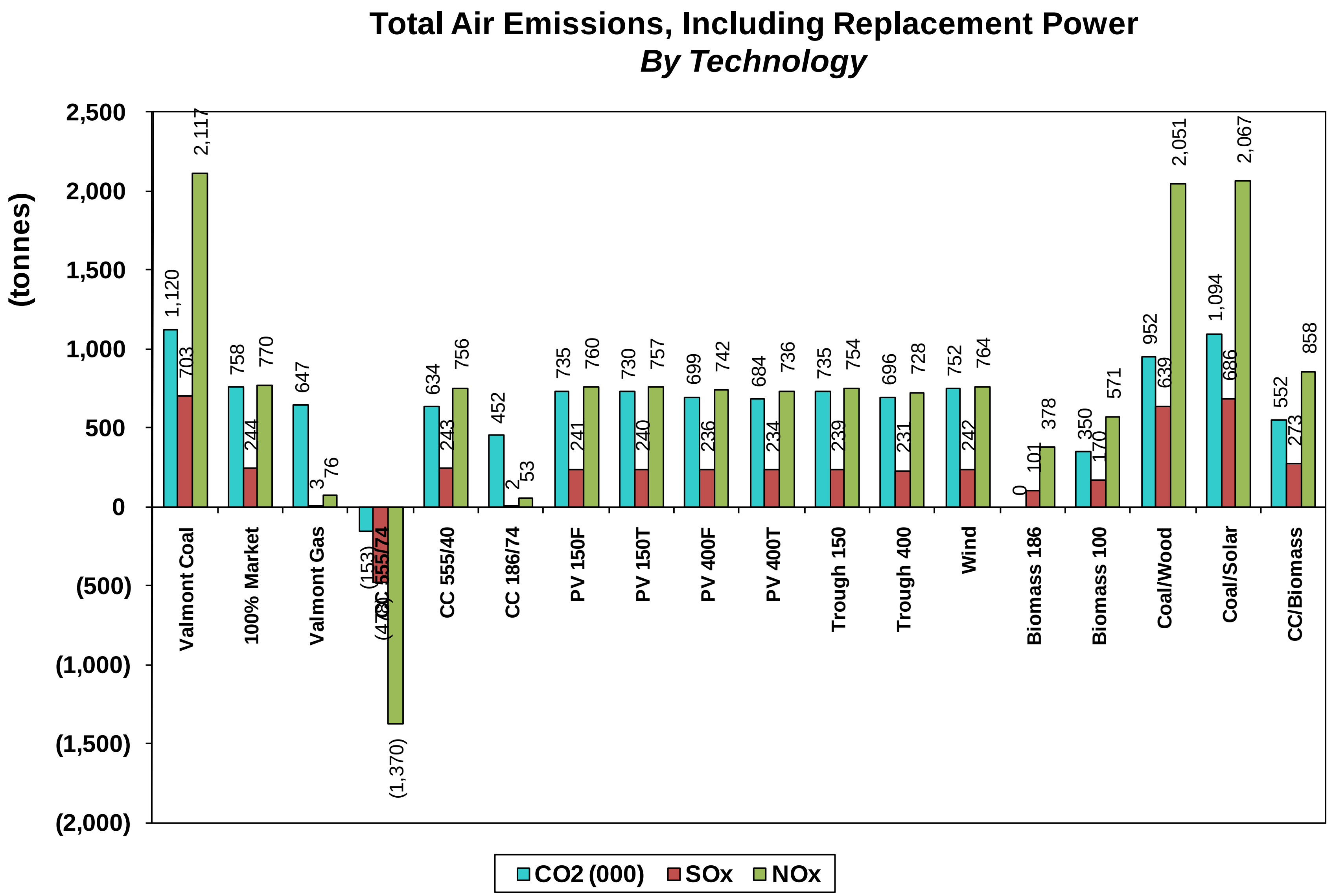

On-Site Levelized Cost
By Technology
Levelized Lifecycle Cost ($/MWh)
$200
$150
$100
$50
$-
$(50)
Valmont Coal
100% Market
Valmont Gas
CC 555/74
CC 555/40
CC 186/74
PV 150F
PV 150T
PV 400F
PV 400T
Trough 150
Trough 400
Wind
Biomass 186
Biomass 100
Coal/Wood
Coal/Solar
CC/Biomass
Capital
Fuel
Emissions
O&M
PTC



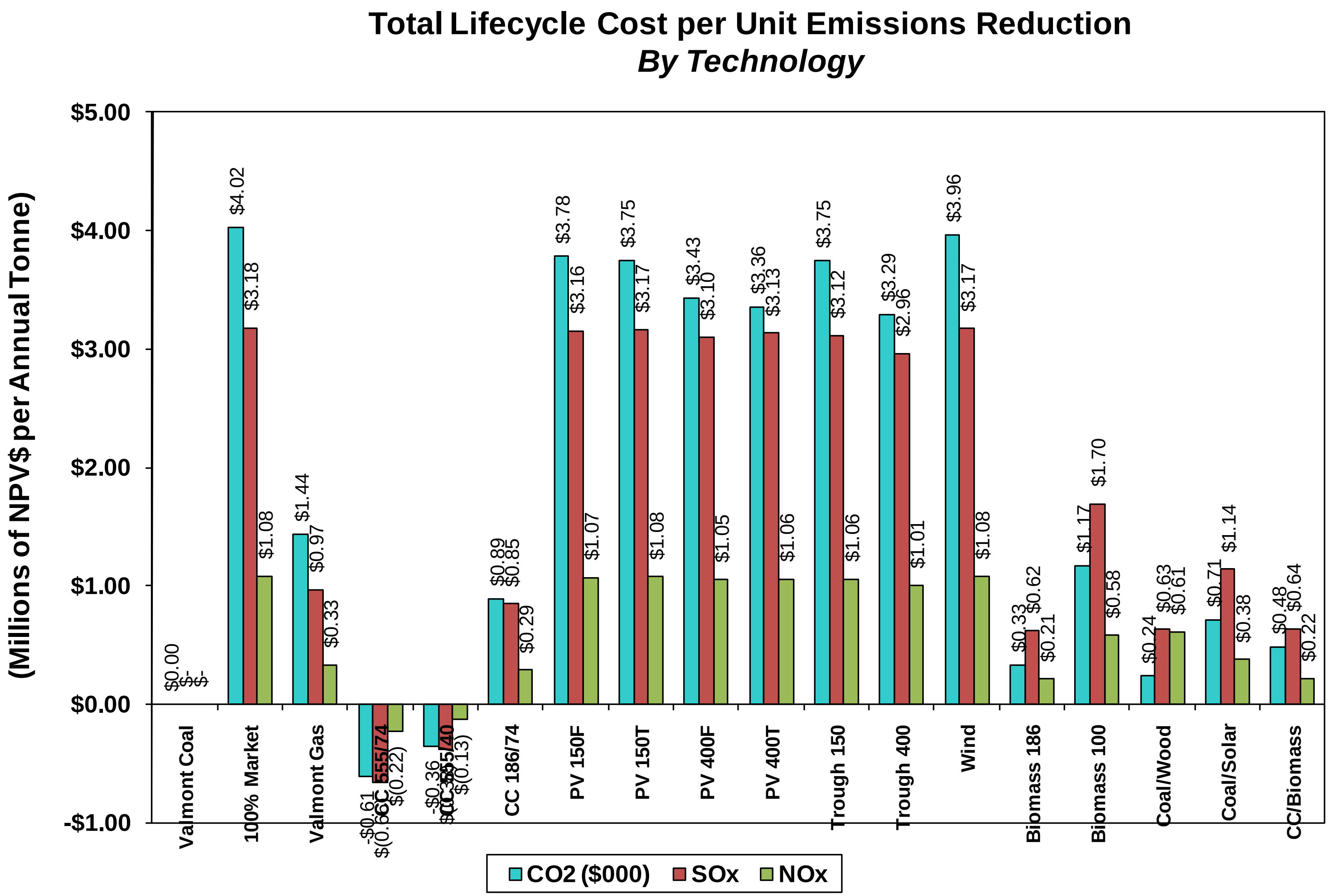
Full Levelized Cost, With Replacement Power Costs
By Technology
Levelized Lifecycle Cost ($/MWh)
$160
$140
$120
$100
$80
$60
$40
$20
$-
$(20)
$(40)
$31
$137
$80
$(26)
$18
$74
$137
$137
$136
$138
$136
$133
$137
$58
$97
$34
$32
$51
Valmont Coal
100% Market
Valmont Gas
CC 555/74
CC 555/40
CC 186/74
PV 150F
PV 150T
PV 400F
PV 400T
Trough 150
Trough 400
Wind
Biomass 186
Biomass 100
Coal/Wood
Coal/Solar
CC/Biomass


Annual On-Site Air Emissions
By Technology
Annual Emissions (tonnes)
2,500
2,000
1,500
1,000
500
0
Valmont Coal
100% Market
Valmont Gas
CC 555/74
CC 555/40
CC 186/74
PV 150F
PV 150T
PV 400F
PV 400T
Trough 150
Trough 400
Wind
Biomass 186
Biomass 100
Coal/Wood
Coal/Solar
CC/Biomass
CO2 (000)
SOx
NOx
1,120
703
2,117
647
3
76
1,350
6
158
738
3
86
452
2
53
101
378
57
215
952
639
2,051
1,094
686
2,067
369
31
155


On-Site Air Emissions per MWh Generated
By Technology
(tonnes/MWh)
Valmont Coal
100% Market
Valmont Gas
CC 555/74
CC 555/40
CC 186/74
PV 150F
PV 150T
PV 400F
PV 400T
Trough 150
Trough 400
Wind
Biomass 186
Biomass 100
Coal/Wood
Coal/Solar
CC/Biomass
CO2 (000)
SOx
NOx



Total Air Emissions, Including Replacement Power
By Technology
(tonnes)
2,500
2,000
1,500
1,000
500
0
(500)
(1,000)
(1,500)
(2,000)
Valmont Coal
100% Market
Valmont Gas
CC 555/74
CC 555/40
CC 186/74
PV 150F
PV 150T
PV 400F
PV 400T
Trough 150
Trough 400
Wind
Biomass 186
Biomass 100
Coal/Wood
Coal/Solar
CC/Biomass
1,120
703
2,117
758
244
770
647
3
76
(153)
(478)
(1,370)
634
243
756
452
2
53
735
241
760
730
240
757
699
236
742
684
234
736
735
239
754
696
231
728
752
242
764
0
101
378
350
170
571
952
639
2,051
1,094
686
2,067
552
273
858
CO2 (000)
SOx
NOx



Total Lifecycle Cost per Unit Emissions Reduction
By Technology
(Millions of NPV$ per Annual Tonne)
$5.00
$4.00
$3.00
$2.00
$1.00
$0.00
-$1.00
Valmont Coal
100% Market
Valmont Gas
CC 555/74
CC 555/40
CC 186/74
PV 150F
PV 150T
PV 400F
PV 400T
Trough 150
Trough 400
Wind
Biomass 186
Biomass 100
Coal/Wood
Coal/Solar
CC/Biomass
CO2 ($000)
SOx
NOx
$4.02
$3.18
$1.08
$1.44
$0.97
$0.33
$(0.22)
$(0.13)
$0.89
$0.85
$0.29
$3.78
$3.16
$1.07
$3.75
$3.17
$1.08
$3.43
$3.10
$1.05
$3.36
$3.13
$1.06
$3.75
$3.12
$1.06
$3.29
$2.96
$1.01
$3.96
$3.17
$1.08
$0.33
$0.62
$0.21
$1.17
$1.70
$0.58
$0.24
$0.63
$0.61
$0.71
$1.14
$0.38
$0.48
$0.64
$0.22