

Conditional Firm Transmission Capacity: an Alternative Strategy for Wind Farm Access to Markets

Debt investors financing a wind farm nearly always require the developer have firm electric transmission capacity, a substantial hurdle since little firm capacity is available. Available transmission capacity (ATC) is already reduced by the mere existence of numerous but infrequently occurring contingency conditions. Yet often, transmission lines operate well below full capacity and only some flow gates become constrained a significant percentage of the time. Often, this physically available but unused transmission capacity is wasted.

FERC order 890 provides for a new type of “conditional firm” contract to take advantage of transmission that could become available with nearly the same quality as firm capacity, except for specific conditions for curtailing. In many cases, these would only occur a limited percentage of the time. Even firm capacity is curtailed by the grid operator in contingency conditions, so “firm” is hardly an ironclad guarantee of grid access.

Although this new type of capacity would introduce additional factors that could reduce effective wind production, the conditions leading to curtailment can be analyzed and their risk assessed. Thus a wind plant need not have firm capacity to meet 100% of its peak. Curtailment risk is no different than other risks investors are familiar with, such as net capacity factor. When used judiciously, conditional firm capacity may lead to improved wind farm economics, or even the possibility of building a project without years of delay for more transmission to be permitted.

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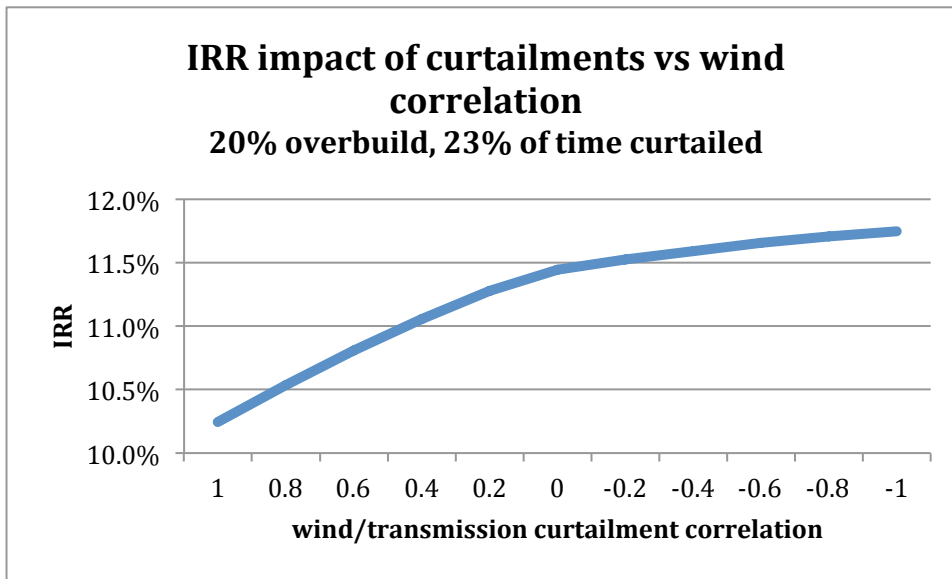
Summary

This white paper defines the opportunity to use less than firm transmission to expand the size of a windfarm, or accelerate the in-service date, while waiting for firm service to become available. Options available for long term contracts with better service quality than non-firm capacity include conditional firm and redispatch service, as defined by FERC Order 890.

To compare options for Wyoming, we assessed the economic impact of curtailments to illustrate potential use of conditional firm or other non-firm capacity across the TOT-3 flowgate connecting SE Wyoming wind regions to Colorado.

Curtailments appear to be manageable because of the relation between existing grid utilization and wind production. This was confirmed by WAPA transmission managers who said that a few hundred MW of conditional firm capacity is likely available across TOT-3, with perhaps another 100MW of capacity by redispatching network resources. As we did not perform a complete wind farm model, the results are conceptual. An in-depth wind analysis and a detailed power system study would more fully define expected results.

Range of curtailment impact on IRR for a Wyoming wind project with 20% overbuild, nominal IRR 11.3% (no overbuild):



The above chart indicates the impact of a high degree of curtailments on a project with a 20% overbuild. For this case, 120MW of wind generation with a production factor of Wyoming are coupled with 100MW of firm transmission capacity and 20MW of non-firm, where transmission curtailments occur 23% of the time. With no curtailments the

project would return 11.3%¹. The correlation between wind production and transmission curtailments is not known due to our lack of data but has a key impact on IRR. As it appears the transmission lines are used most heavily in summer, when the wind is relatively weak, a reasonable conclusion is that curtailments are uncorrelated with wind production, so the net impact on project return may be modest.

Thus, conditional firm and redispatch service would permit a project to be built today with only a modest impact on project economics due to curtailments. This is an alternative to waiting in the firm capacity queue because of the experience and local knowledge that is gained from an operating project. Any impact from curtailments would be temporary since it is relieved when upgrading to firm service, if desired.²

Per FERC rules, the curtailment levels in conditional firm and redispatch service are reassessed every two years *only* if we state we do not want to contribute to network upgrades for firm service. However, if we do wish to upgrade to firm capacity and maintain a queue position, curtailment levels and redispatch costs are fixed through the term of conditional firm or redispatch service *without* biennial reassessments. This further mitigates risks of less than firm service.

Conditional firm/ redispatch service on TOT-3 would be a viable alternative or supplement to capacity on the Trans-Elect project. A diversified approach reduces dependence on winning capacity in the Trans-Elect open season.

To assess in more detail, we need a load flow analysis to quantify the relative impact on different flow gates for different generation connection points. To determine the level of curtailments, historical flow data is required. This is available only from WECC, who is only willing to share data if we become a member of WECC.

WAPA states that another wind developer is already seeking 50 MW of conditional firm capacity on TOT-3.

¹ The IRR here can exceed the IRR of a project with no overbuild because it's assumed that the non-firm transmission capacity is free. We also analyzed a case where the non-firm is not free.

² MJ-With a queue request that commits to fund an upgrade for firm service, we have a potential capital injection at some date in the future. The capital injection will be amortized over rates,

² MJ-With a queue request that commits to fund an upgrade for firm service, we have a potential capital injection at some date in the future. The capital injection will be amortized over rates, presumably at a higher rate than was paid for the non-firm service reflecting the above average cost to provide the service.

Economic Impact of Transmission Curtailments

A wind farm connected to the grid through a constrained transmission line, perhaps sharing the transmission with other network facilities, can face curtailment, affecting project economics. Several alternatives to firm transmission capacity include non-firm, conditional firm and redispatch service. In many cases, firm capacity is simply not available right away, so new generation can only be built with these alternatives. In fact, the purpose of conditional firm and redispatch service is to bridge the gap in time before new transmission facilities may be constructed while taking advantage of existing serviceable capacity.

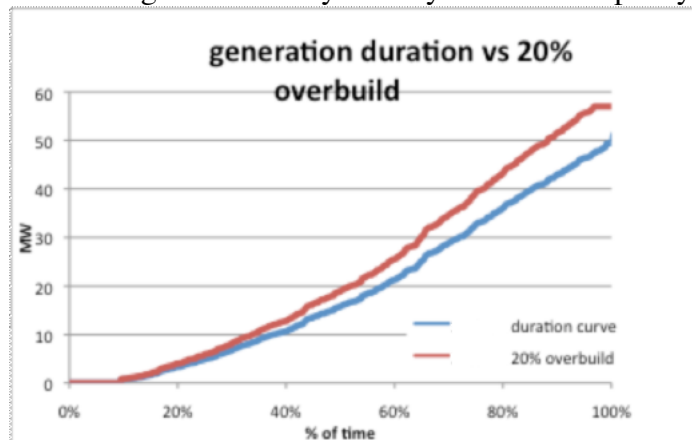
In real-world operation, firm capacity may be curtailed, local marginal prices may be affected or even become negative. For simplicity, in this paper we assume firm capacity is never curtailed, consider curtailments of non-firm capacity some % of the time, and ignore local marginal price effects.

After reviewing wind resource and generation curves, we present a first simple case of a turbine oversized relative to a single radial line. The second and third cases consider a wind turbine connected to a line, perhaps shared with some other resource with priority over an incremental amount of capacity. Here, the wind generator's primary capacity is firm but some additional capacity is non-firm, with interruptions occurring some % of the time. In these two cases we examine various curtailment scenarios, looking especially at the economic benefits resulting when peak wind production and transmission curtailments do not occur simultaneously.

Curtailments on a Single Radial Line

The simplest scenario is a wind farm connected radially with a fixed quantity of firm capacity, where the wind farm is oversized relative to the transmission available, and where additional transmission capacity is never available. This creates a “hard” constraint. For example, a 120MW wind farm is connected and only 100MW of capacity are available to it, while other generators may use any additional capacity.

**Northeastern
wind case:**

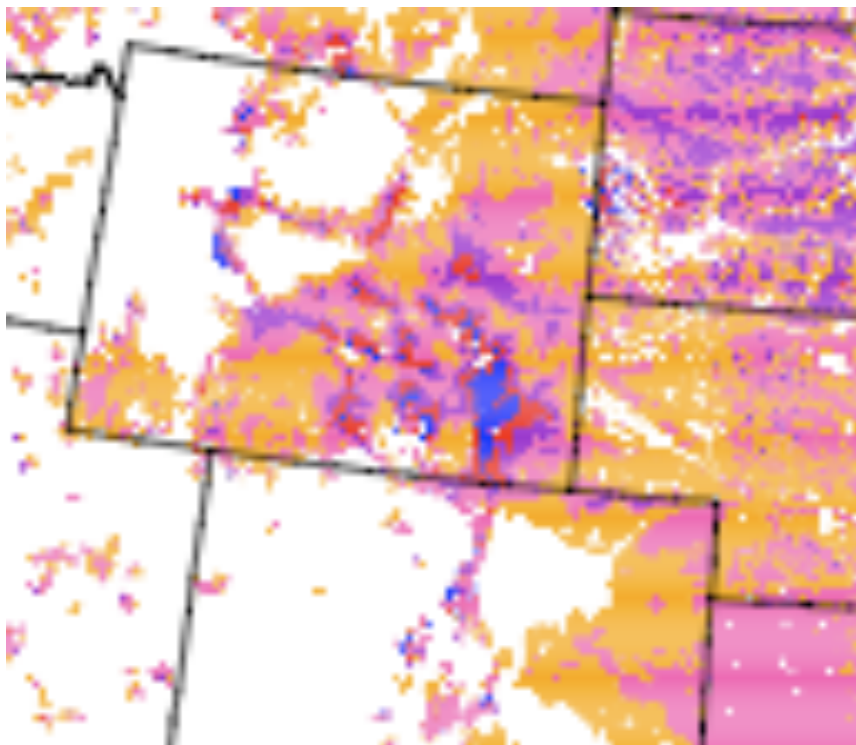


The economic effect of the curtailment depends solely on the statistics of the wind resource combined with the power curve for the generator. In a case where we have several years of wind data, for a typical wind farm in Maine, the wind production curve can be obtained.






The wind duration curve for this 57MW plant is shown in blue, compared to a case where a Maine wind farm was overbuilt by 20%. In this case, curtailments occur whenever the total plant production exceeds the original size limit of 57MW, and this oversized plant becomes ‘pegged’ at a maximum limit.

As the wind resource for the above Northeastern location did not reach maximum production for the year data was collected (2004), a unit oversized for transmission achieves additional output without transmission constraints. The effective load factor only decreased from 33.4% to 33.3%. Thus, looking only at the wind data for this year, the turbines should be oversized compared to transmission constraints.

The wind resource in Wyoming is stronger, as indicated in the map below. Class 7 resource can be tapped in the vicinity of Medicine Bow in SE Wyoming.



NREL Wind Res

Wind Power C		
Wind Power Class	Resource Potential	Wind Power Density at 5 W/m ²
	3 Fair	300 - 400
	4 Good	400 - 500
	5 Excellent	500 - 600
	6 Outstanding	600 - 800
	7 Superb	800 - 1600

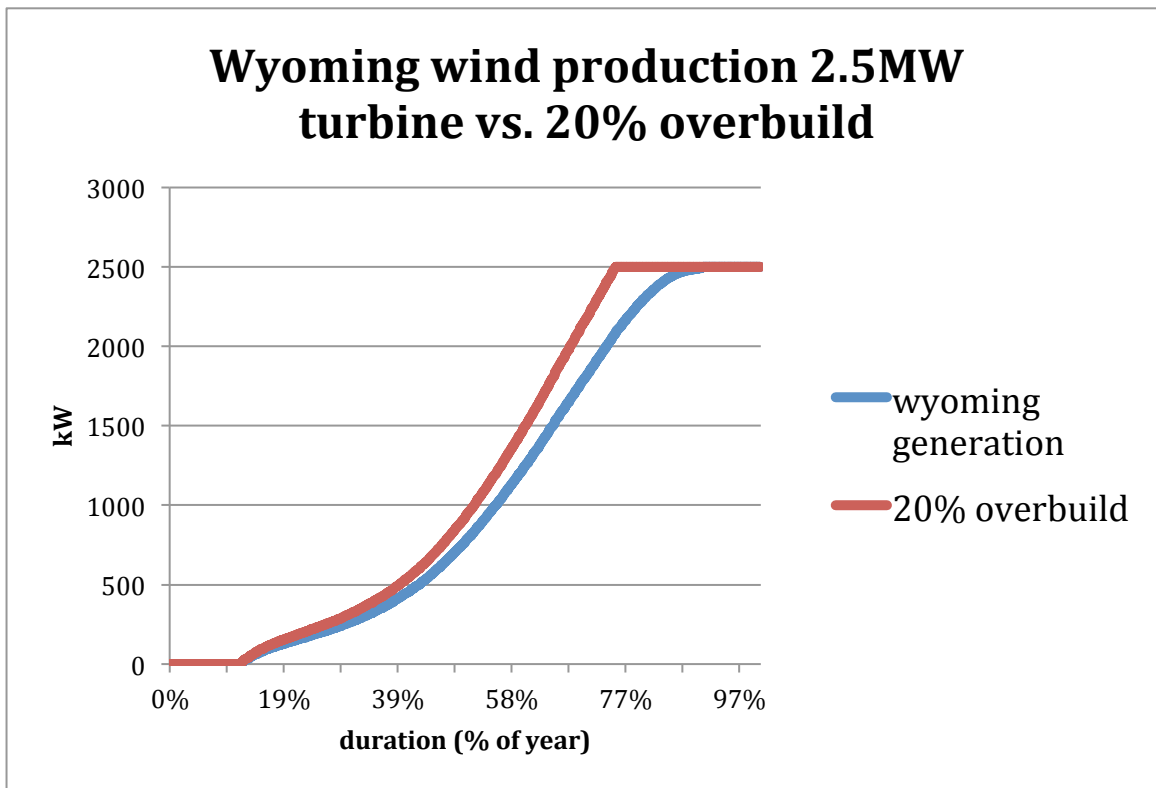
^a Wind speeds are based on a Weibull

We used preliminary meteorological data covering one year, from met towers near First Wind’s properties in SE Wyoming. Although we rescaled the wind speed data using the turbine generation curve to produce hourly turbine production levels, we did not take into account important effects such as wake loss, turbine farm layout, blade icing or turbine unavailability. These effects reduce the frequency of peak farm output and tend to favor

oversizing the farm relative to the transmission capacity available. An economical project design would take them into account.

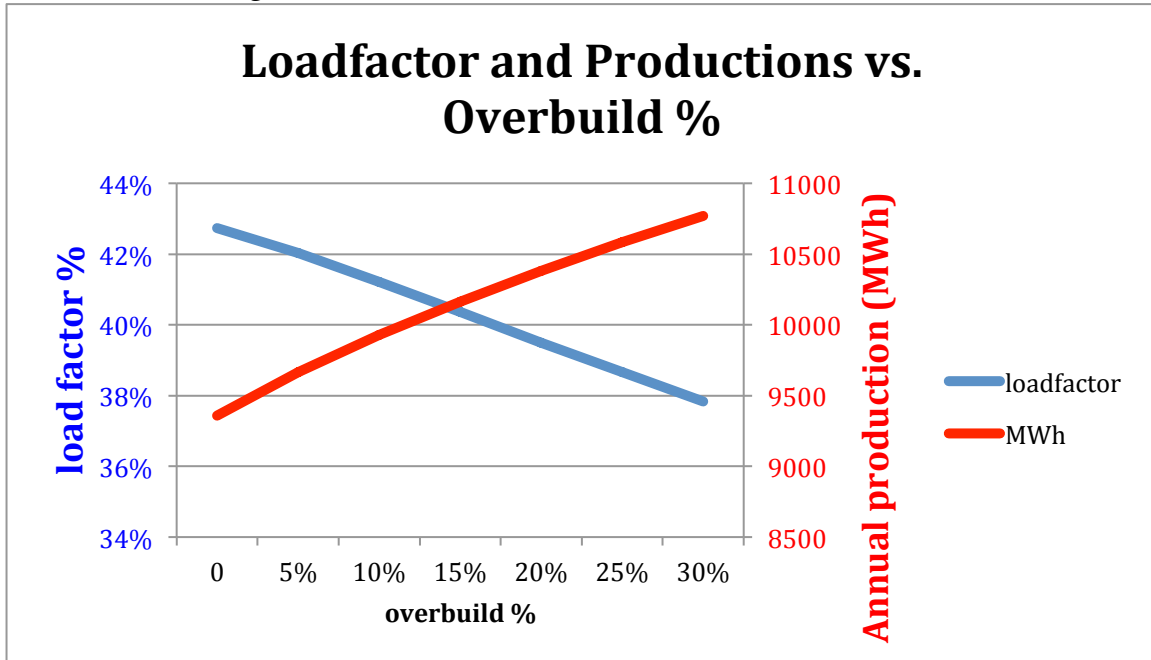
The wind curve has been processed to yield the effective generation with a Clipper turbine, as in the generation duration curve below. Nearly 10% of the time the turbine is producing maximum output. The rise in output is steeper compared to the far gentler slope in the Maine wind data, with an effective load factor of 42.7%. Wyoming wind is known to be strong and sustained, with yearly averages tending towards the 40 – 42% range, underscoring how the data sample we've used is inadequate for more than conceptual analysis.

The duration curve is compared to a turbine oversized by 20% for transmission capacity. That is, we've assumed a 3MW turbine connected to a 2.5MW line. Here, maximum output of 2.5MW is reached 23.3% of the time with this limited wind data sample. The effective load factor decreases from 42.7 to 37.8% and period production increases from 9350 to 9942 MWh. Thus compared with a Northeastern wind production profile, Wyoming results in far more curtailments because of the relative wind strength.

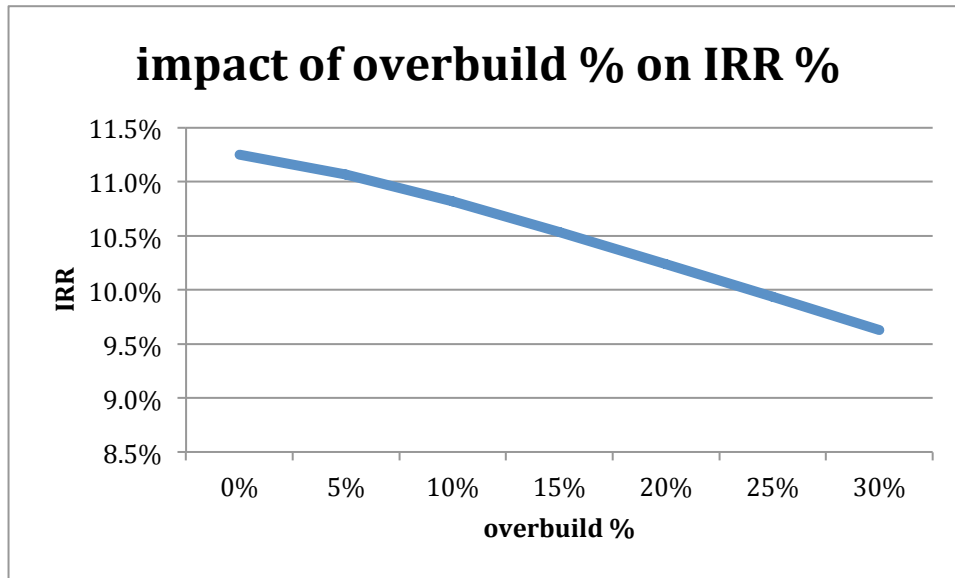


The effect of different levels of overbuilding can be inferred from the chart below, indicating growth in production vs. overbuild together with the effective load factor. As overbuild increases, output also increases, reflecting higher production at moderate wind

speeds where constraints don't come into play. The effective load factor does, however, decrease, reflecting the onset of curtailments.



Financial analysis indicates asset returns decline with increasing overbuild in the hard curtailment case. The model assumptions include: 95\$/MWh power price, 2000\$/kW capital and construction costs, 37% tax rate with a refundable production tax credit of 19\$/MWh, 5 year depreciation, a 2.5% royalty for land rights among others. It's assumed further that the transmission constraint persists for the 25-year project life while a more realistic strategy would include the option to upgrade to firm capacity when the generator's queue position permits, significantly mitigating the impact of curtailments.



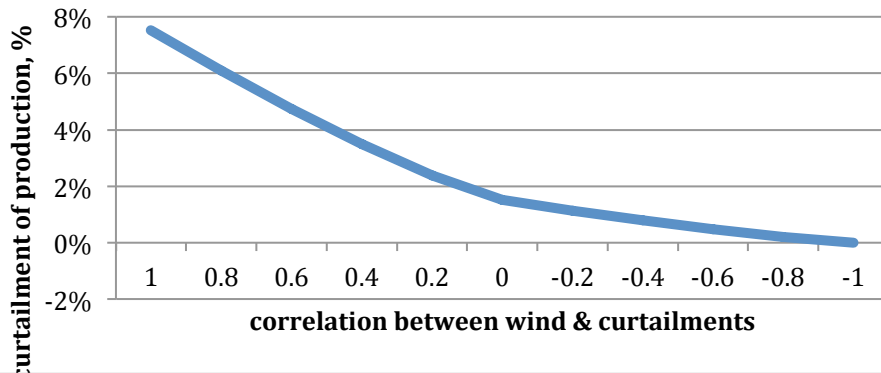
Curtailments on a shared transmission facility with variable ATC

More complex is the case where some of the capacity is firm but some is non-firm or conditional firm that has some probability of being curtailed at any time. The transmission curtailments might or might not occur at time of peak wind production. This applies to a transmission line shared by multiple generators and where the proposed wind turbine has lower relative priority for a portion of its capacity.

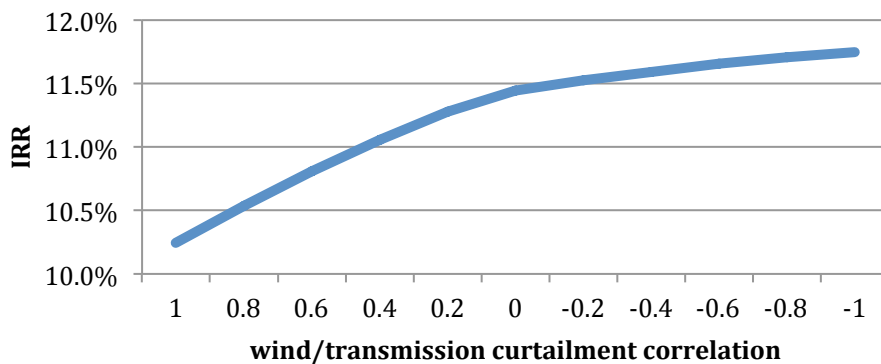
For curtailments perfectly correlated with peak wind production, the result is the same as for the hard curtailments of the wind turbine connected to a single dedicated line. As the correlation between peak wind and transmission falls to 0 (uncorrelated) the impact of the curtailments is moderated. For negative correlation the curtailments occur exactly when the wind is *not* producing, thus the economic impact is mitigated further.

To draw a parallel to the single line, hard curtailment case, we focus on a 20% overbuild (ie. 3MW turbine connected to a 2.5MW line) with the same curtailment frequency for the overbuild portion in the hard curtailment case: 23.3%.

impact of wind/trans correlation on curtailment, 20% overbuild, 23% curtail



IRR impact of curtailments vs wind correlation 20% overbuild, 23% of time curtailed

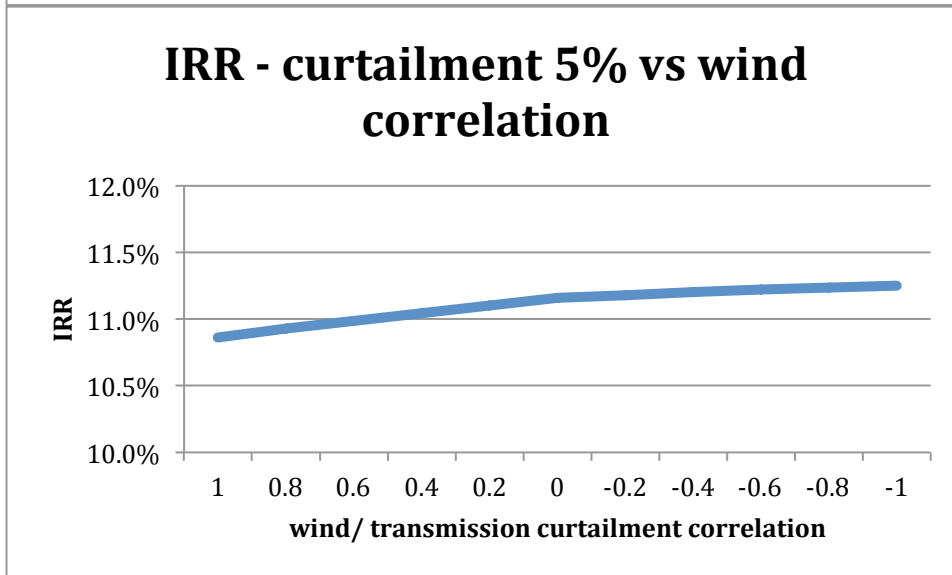
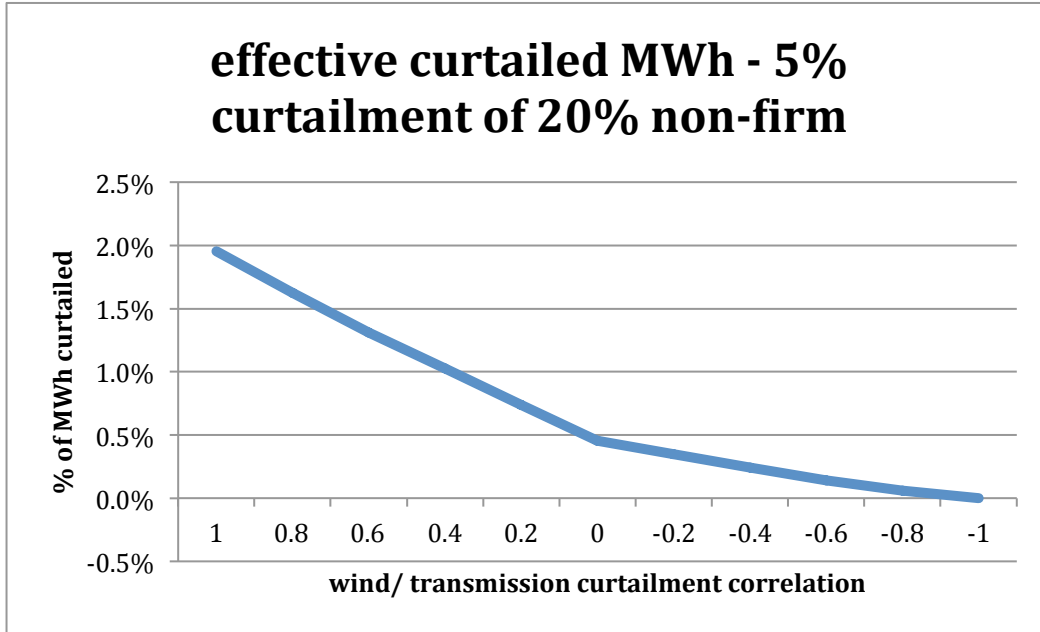


Reducing the correlation between curtailment and production significantly reduces the degree of curtailments – from 8% of the total energy production to zero for perfectly anti-correlated curtailments. Most of the benefit occurs when the wind and transmission curtailments are simply uncorrelated. Likewise, reducing the correlation increases the project returns to the point where, with a correlation of 0, the IRR exceeds the case without overbuilding at all because we assumed here that the interruptible transmission capacity is free.

Non-firm Capacity

The third case is the purchase of a fixed quantity of firm transmission capacity complemented by a quantity of non-firm or conditional firm capacity. In the case where

the wind turbines are overbuilt by 20% compared to the quantity of firm capacity, and it's understood that the non-firm or conditional firm capacity would be curtailed in full 5% of the time, the net curtailments are greatly reduced from the previous case where they occurred 23.3% of the time. Here it's assumed the non-firm capacity is paid for at the same rate as for the firm capacity, given the low level of curtailments.

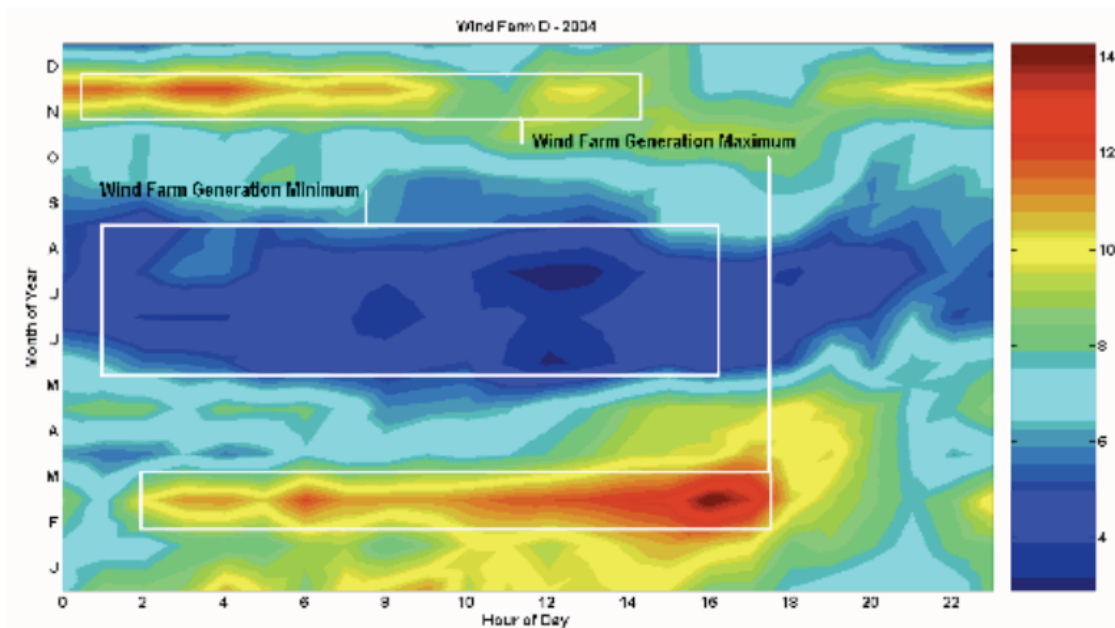


The analysis indicates that when curtailments are 100% correlated with peak wind production, that net reduction in MWh produced is 2%; when the curtailments are uncorrelated with wind production, curtailments result in a net 0.5% reduction in production. Likewise, the financial returns increase up to 11.25%, but do not exceed the returns for the 2.5MW project with no overbuilding.

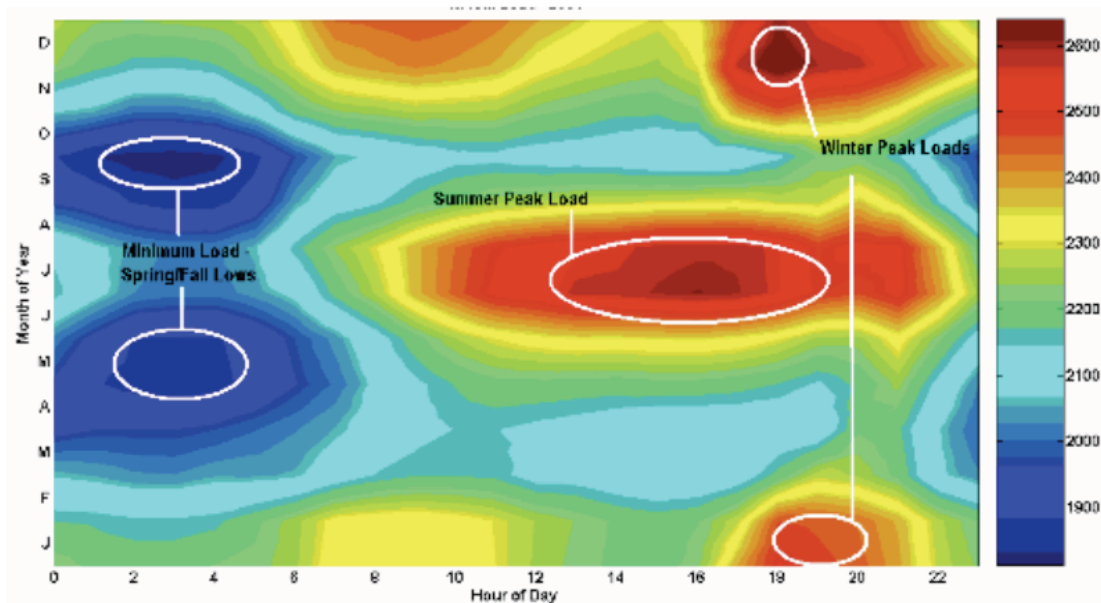
Wyoming Wind Resource

The above shows the key importance of understanding the correlation between wind and transmission curtailments. Unfortunately we lack current data on [both Wyoming wind](#) and on occurrence of potential transmission curtailments for the relevant flow gate in Wyoming, the TOT-3 interface. Some inferences can be made from published data on Wyoming wind and system loads, published by NREL. These wind data were gathered at a turbine location on the Wyoming Colorado border, approximately 40 miles west of the Colorado-Nebraska border, thus are perhaps representative of wind resources in SE Wyoming:

12x24 diurnal pattern for WAPA wind



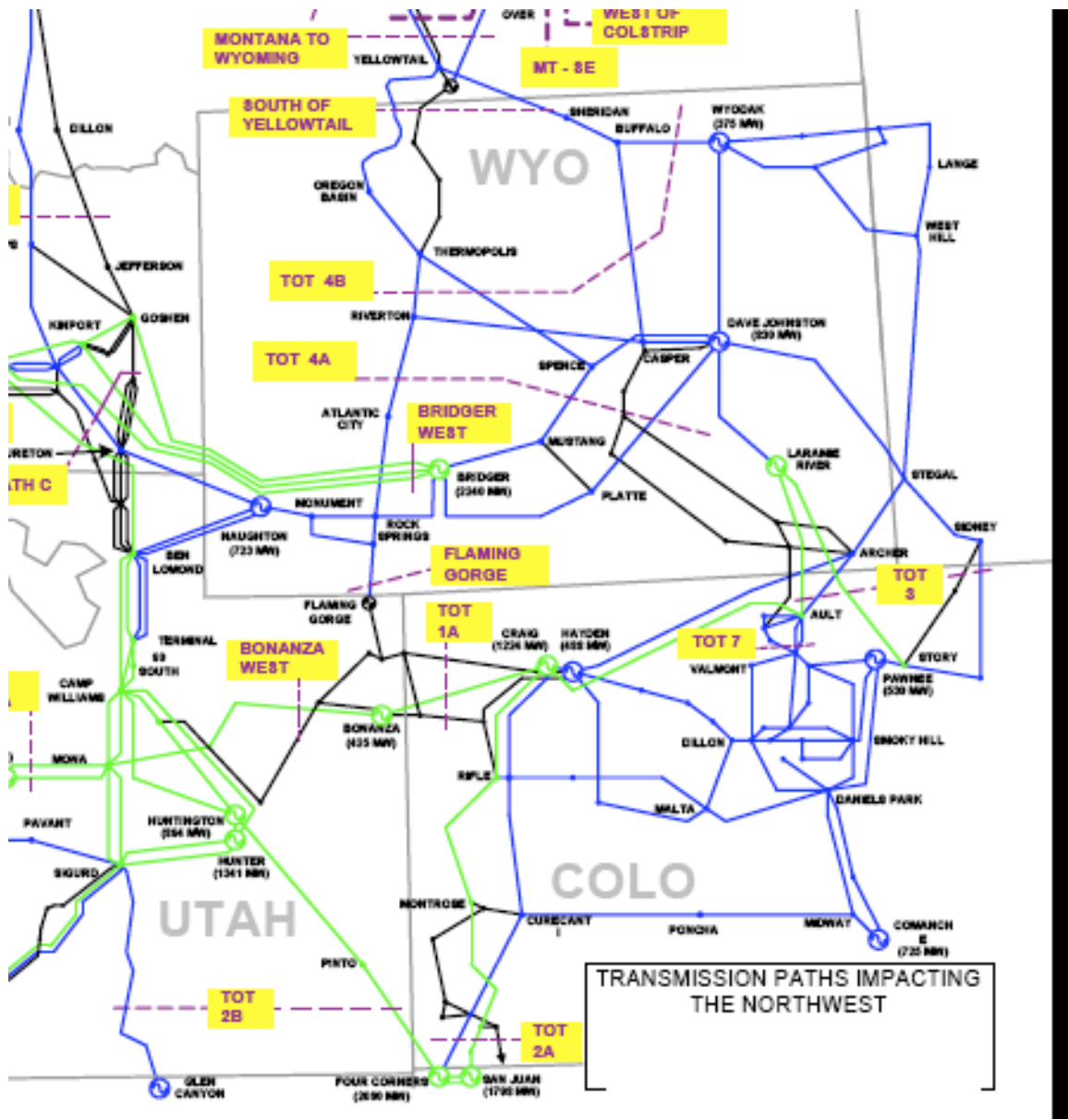
Western Area 12x24 Diurnal Load



These visualizations, taken together, indicate that the wind peak production times, during February and March together with a secondary peak in November, correlate poorly with the peak loading during the summer months or the secondary peak load, during December and January. In fact the summer trough in wind production appears well-correlated with summer peak loading. Such negative correlation would mean that capacity reductions would occur precisely when wind generators could best accept them, improving project returns.

Transmission and flow data is available only from WAPA and WECC. These bodies maintain their data and will only be willing to share if we attain WECC membership. Thus, WECC membership is essential if we are to gain a reasonable handle on curtailments in the WECC/ WAPA system.

Regional Transmission Overview



The transmission grid in the Wyoming/ Colorado area is under combined ownership of WAPA (Western Area Power Authority) and PacifiCorp, with PacifiCorp owning the lines in the Western half of Wyoming, WAPA in the eastern half. Wapa operates the lines through into Colorado except for the Denver vicinity, owned by Public Service of Colorado, (PSCo), a subsidiary of Xcel Energy.

A closeup of the lines in the Wyoming/ Colorado border area, above, shows the line through the constrained flowgates TOT-7 and TOT-3. TOT-3 is operated by WAPA, and owned by a consortium consisting of

Missouri Basin Power Project (MBPP) – 70.5%
Tristate Generation (TSGT) – 0.83%
WAPA – 24.93%.

MBPP is a group of companies:

Basin electric power cooperative (BEPC) 61.7% of MBPP
Tri-state generation (TSGT) 36.2% of MBPP
Wyoming Municipal Power Agency 2.1% of MBPP

These shareholders own all the firm capacity across the TOT-3 flowgate – there is no further firm capacity available so any requests for transmission across this path would either be non-firm, conditional firm, or subject to redispatch availability pending the construction of new capacity. This is scheduled for 2014 with the Transelect project. Other upgrades in the PacifiCorp portion of the network are scheduled for 2012 and 2014.

The impact of a new generation plant on the grid depends on location. Projects located near Laramie WY are expected to have a large impact on TOT-3. On the other hand, it has been suggested that a project in SE Wyoming such as near Medicine Bow might only have partial impact on TOT-3. To know for sure, it is critical to have a load flow analysis performed.

In addition to scheduled flow to the Denver area, TOT-3 is a path for loop flow originating at Bonneville (BPA) facilities. This flow is destined for western markets but, following parallel paths, travels through TOT-3. While such flow is not scheduled and does not subtract from the capacity formally committed by WAPA through TOT-3, allowances have to be made in the TOT-3 schedules to permit these flows. The WAPA and WECC capacity determination procedures do not allow loop flows through a line without the permission and knowledge of the line operator. When this is granted, we are not aware of a formal process that allocates the capacity used by these unscheduled flows, and it does not appear that capacity use by unscheduled flows is charged for. Since there is no clear process for the approval of capacity use by unscheduled flows, there is the possibility here for discrimination in access to transmission capacity.

According to WAPA, the TOT-3 flow gate is not heavily constrained, or, depending on the time of year, heavily used. This conflicts with the data in the Rocky Mountain Areas

Transmission Study (RMATS) of 2003-04, which suggested that TOT-3 is somewhat heavily used. WAPA believes that hydro conditions have changed in recent years, substantially reducing the loop flows through TOT-3 that have affected it earlier.

WAPA Procedures for Determining ATC and Availability

The above raises the question of how, precisely, WAPA determines ATC. In fact, this is *not* assessed by physical flows since these occur in real time and enough advance notice needs to be provided so that transmission owners may release anticipated unused capacity to OASIS. FERC requires that day-ahead schedules be calculated on a good-faith basis, allowing for appropriate reserves, and indeed this is what WAPA has implemented.

On an hourly basis, WAPA forecasts the hourly flows for the next 24 hours. For its capacity, 25% of TOT-3, it releases 80% of anticipated unused capacity to OASIS, keeping the remaining 20% in reserve for unanticipated loads, weather changes and reliability purposes.

Sometimes physical flows exceed scheduled, as when loop flows occur, other times it is the opposite case. Ray Vojdani, director of transmission at WAPA said that unscheduled capacity on TOT-5 was typically twice the unused physical capacity. However, on TOT-3, in recent years, unscheduled capacity and unused physical capacity were about the same on average. TOT-1 and TOT-2A have 30% more scheduled flow than physical flow. As an example, WAPA disclosed these recent flows and schedules:

5/19/08	8PM	1130PM
scheduled	1103	609
actual	776	735

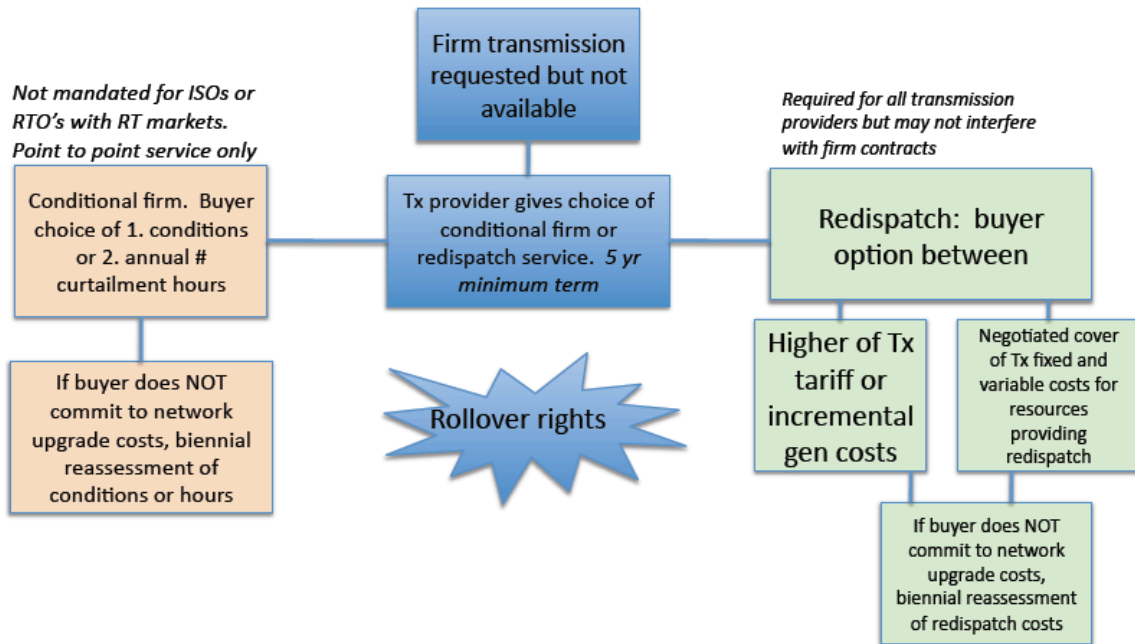
Transmission capacity is made available to OASIS on a scheduled, not physical flow, basis. Curtailments occur when *either* physical flows or scheduled flows exceed limits, with non-firm customers being curtailed first. Because the total transmission capacity (TTC) on TOT-3 is subject to thermal limits (from a high of 1603MW to a low of about 800MW) and is recalculated on an hourly basis and implemented in WAPA's SCADA system. This, in part, explains why summer curtailments are more extensive than other seasons'.

Ray Vojdani, director of Transmission for WAPA – Mountain Region, stated that several hundred MW could be available conditional firm without a problem, and that another wind developer was currently seeking 50-60MW of capacity via this route. He also stated that while WAPA had never been approached about redispatch service, this would be investigated in good faith. He thought that despite limited hydro storage, perhaps 100MW of capacity could be made available through redispatch of hydro plants and that coal plants could also be redispatched.

Appendix:

Regulatory Basis for Less than Firm Transmission Access

FERC order 890 set forth a regulatory regime whereby generators and others seeking firm transmission capacity in areas where none (or not enough) is available may obtain acceptable levels of service as a bridge to a time when firm capacity does become available, or even retain this new level of service indefinitely if it is not desirable to pay the costs needed for transmission upgrades. The two types of service that FERC has required are “conditional firm” capacity, and “redispatch service.”



The flowchart indicates the process and service options. A party requesting firm long term capacity is denied (such a request is a precondition for obtaining conditional firm capacity). This would be the case for anyone seeking transmission access from SE Wyoming to Colorado, where there is simply no firm capacity available. The customer may then request either redispatch service or a new class of service called “conditional firm.” The request must be a long term capacity request exceeding a five year term, and for conditional firm, must be point to point rather than for network service. The transmission provider will further advise what the costs are for upgrading the facilities so that customer may decide whether or not to participate in an eventual system upgrade.

The purpose of the conditional firm (CF) capacity is that most of the time capacity is available but that for a certain number of situations the provider could foresee potential curtailments. In this case, the provider will advise a. how many hours per year the customer would be subject to curtailments – not per month – **and** b. what conditions would exist to require a curtailment. The customer elects either hours (a) or conditions (b).

The price of the CF capacity is the same as for firm long term capacity. In view of this high level of service, outside of the curtailment hours or conditions, the capacity is treated the same as firm capacity, with any additional curtailments on a pro-rata basis with firm customers. During curtailment hours and conditions, a holder of CF capacity has priority over non-firm customers. In general, CF has “secondary network curtailment priority.”

If the customer is willing to incur the costs for transmission upgrades and receive an eventual transfer to long term firm capacity, then the # of curtailment hours or conditions are fixed for the duration of the contract. If, on the other hand, the customer is not willing to incur transmission upgrade costs, then the provider has the right every two years to reassess the # of curtailment hours or conditions. Rollover rights apply.

Redispatch is an existing service, modified by the recent FERC order 890. Several generators sharing transmission with a constraint can accommodate each other through offsetting dispatch. If a wind producer conflicts with another network resource who wishes to generate at the same time, the wind producer can ask the other generators to ramp down their generation while making the other generator whole by offering to pay them for any cost increase due to sourcing power on the other side of the constraint. The wind producer is not liable for the entire cost of the second generator’s power, only for the increase in cost across the constraint.

For a hydro facility with storage or a coal producer such a trade can be easily accommodated since the second generator’s production can be easily shifted in time by running water through turbines or burning coal from the fuel pile when the wind is not blowing.

FERC requires that any regulated transmission operator with generation network assets (such as WAPA or Pacificorp) make redispatch service available with prices set, at the customer’s choice as either

- A. the highest of the incremental generation costs or the firm transmission tariff, or
- B. a negotiated agreement taking into account the generator’s incremental and fixed costs.
- B. For customers willing to invest in a transmission upgrade, this cost is fixed at the time of the transmission agreement, but for customers unwilling to make such a contribution, the costs are reassessed every two years. Rollover rights apply.

Note that this service applies to network generation resources only. For non-network generation, the transmission operator may provide referrals but the third party generator contracts with the transmission customer independently.

