CHAPTER 12
RESULTS AND CONCLUSIONS

Ascend's analysis identifies flexible capacity as the economically optimal near term resource additions. The addition of flexible capacity in the form of Internal Combustion Engines provides reliable capacity at the lowest cost.

Introduction

This chapter discusses NorthWestern's optimal capacity expansion analysis and the results and conclusions of NorthWestern's portfolio analysis. Several conclusions are evident from the analysis:

1. NorthWestern cannot continue to rely upon the market or other utilities to meet such a large percentage of NorthWestern's capacity requirements. Prudency in this context means customers will pay higher costs coupled with higher risks
2. Applying the results from PowerSimm and PowerSimm Planner will lead to a more efficient and lower cost portfolio of resources at lower risk than relying upon market purchases.
3. Carbon cost is a significant risk factor in NorthWestern's portfolio analysis.
4. NorthWestern's resource portfolio, already low carbon, remains low carbon when current RPS requirements are added to the Economically Optimal Portfolio ("EOP").
5. Intermittent renewable resources, like wind and solar, do not address NorthWestern's need for capacity resources and are not selected.
6. Adding wind and solar PV resources to the EOP increases NPV cost.

7. Additional wind and solar PV beyond RPS requirements further lowers carbon, but at significantly higher costs.
8. CPS2 compliance was the basis for determining regulation need in this Plan. RBC is the new compliance standard and requires flexible resources.
9. The EOP does not address NorthWestern's need for additional capacity resources to provide a minimal level of planning reserve margin.
10. NorthWestern's fleet of generation resources will be operated for additional and varied purposes, lowering overall costs to consumers.
11. DGGS will no longer be used exclusively as a regulation resource, but will be used to provide a variety of generation services.

Options for Capacity Expansion

The evaluation of near-term capacity resource additions considers both the potential for new generation assets to reduce NorthWestern's capacity deficit while also addressing system needs for flexible generation to integrate current and additional intermittent renewable resources. PowerSimm Planner was used to perform optimal capacity expansion planning and to assess the long-term path toward resource adequacy.

As discussed in Chapter 7, NorthWestern has a physical resource adequacy of -28% for 2016, which is equivalent to being 338 MW short. Unconstrained, PowerSimm Planner would fill this gap in a single year, creating an impossible build-out schedule. To create a more realistic and manageable schedule, NorthWestern constrained PowerSimm Planner such that it achieves minimum levels of resource adequacy over approximately ten years. NorthWestern selected ten years based upon the work of the NWPCC Resource Adequacy Advisory Committee ("RAAC"). Ten years allows NorthWestern to achieve minimal resource adequacy in about the same time frame that 2,400 MW coal-fired generation is scheduled to retire in this region, which was the principle driver of regional resource need in the RAAC's analysis. NorthWestern also considered the potential impacts of the Clean Power Plan on the Colstrip facilities. This extended time frame also contains an inherent flexibility in resource timing and acquisition, as opposed to a "build-it-all-at-once" strategy. Not considered at the time the decision was made to achieve minimal resource adequacy in ten years was the current legislative efforts underway in Oregon and Washington to end "coal-by-wire" purchases from Colstrip. Those efforts underscore the need for NorthWestern to proactively address and resolve its current capacity deficit.

Constrained to achieve minimal resource adequacy in ten years, PowerSimm Planner determined timing and types of resource additions from a range of available supply options.[1] The key characteristics of generic generating units evaluated for capacity expansion planning are summarized in Table 12-1.

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[1] Although demand side resource options were not considered, these resources have value and will be considered in future analysis with the development of demand side programs.

Table 12-1 Summary of Resource Inputs for Capacity Expansion Planning

Resource Description	Fuel Source	Technology	Net Capacity (MW)	Capital Cost ($ / kW)	Fixed O&M ($ / kW-yr)	Variable O&M ($ / MWh)	HHV Heat Rate (Btu/kWh)	Escalation Rate (% /year)
CCCT (1x1)	Natural Gas	GE 7FA.05 ACC[1]	308	$1,400	$10	$3	6,528	2.0%
CCCT (Duct Firing)	Waste Heat	GE 7FA.05 ACC[1]	40	$0	$12	$0	8,546	2.0%
SCCT - Small Aeroderivative	Natural Gas	PW FT8	53	$1,017	$6	$5	10,500	2.0%
SCCT - Large Aeroderivative	Natural Gas	GE LMS100	93	$1,187	$17	$3	8,867	2.0%
SCCT - Frame	Natural Gas	GE 7EA	79	$997	$12	$3	11,286	2.0%
ICE - Internal Combustion Engine	Natural Gas	Wartsila 18V50SG	18	$1,280	$11	$5	8,314	2.0%
Utility Scale Solar PV[2]	Solar		25	$3,176	$43	$1		-1.0%
Wind[3]	Wind		40	$1,980	$38	$2		-0.5%

Table Notes:
Capacity for natural gas-fired resources estimated at 3,500 ft. elevation
[1] ACC = Air Cooled Condenser
[2] Solar fixed O&M is priced in $/kWdc.
[3] Based on build-transfer bids received in NWE's 2015 CREP RFP

Dynamic programming for automatic resource selection determines the optimal expansion path. The optimization routine does this through a two-pass process. The first pass is a backward pass that determines the number of feasible resource additions that satisfy the reserve margin constraints. After determining the feasible sets of generating resources that satisfy the constraints, the dynamic optimization proceeds forward in time selecting the addition of resources that minimizes the NPV of fixed and variable operating costs (second pass).

The reserve margin constraints specified for this analysis start with the current portfolio as it exists today, adds resources to achieve an intermediate requirement of 82% of expected peak load in 2025, then further adds capacity resources to achieve a final requirement of 100% of expected peak load required in 2028. The constraints allow the model to select reasonable levels of generation additions while satisfying the extended multi-year schedule.

Resource additions incorporated in this analysis have specified capital costs, escalation rates, reserve margin contributions, and annual fixed operating costs. These additions are valued against the stochastic simulations so that their values are estimated across the potential future conditions. This variable costs valuation is added to the other inputs, and the sum of these fixed, variable, and capital costs are used to calculate the NPV.

Portfolio Analysis

NorthWestern's portfolio analysis assesses a wide range of potential conditions for load growth, market prices for gas and emissions, and also shows the impact of environmental policies. Table 12-2 shows the input assumptions for each portfolio of resources analyzed. NorthWestern's base case scenario labeled "Current plus Market" captures NorthWestern's current set of resources and relies on market to meet current and future needs. The Current plus Market portfolio also uses NorthWestern's base case carbon scenario and a forecast average annual load growth of 0.8% over 20 years. In addition to the Current plus Market portfolio, other load growth scenarios include a "Low Load Growth" portfolio (0.4% average annual growth rate) and a "High Load Growth" portfolio (1.2% average annual rate).

The base assumption for carbon has an expected price of $20/ton for CO_2 in 2022 and a price distribution range of minimum value of $0/ton and maximum value of $40/ton. A "Low Carbon Cost" portfolio and a "High Carbon Cost" portfolio were also evaluated with a deterministic price at the minimum and maximum of the base case triangular distribution ($0 and $40/ton). Because carbon cost is defined as a variable in the stochastic model without the benefit empirical data, the triangular distribution creates a component of randomness that appropriately reflects the level of uncertainty associated with future implementation of carbon emissions regulations.

Table 12-2 Resource Plan Portfolio Assumptions

	Regulation	Assets	Load	Carbon Price	Fuel/Power Forecast
Current plus Market	50% Hydros 50% DGGS	Basin Creek Colstrip 3&4 Hydros DGGS	Grows by ~0.8%/year	Triangular distribution Mode = $20/ton Max=Roughly 2xMode. Starts in 2022 and escalates	Simulated monthly forwards from current CME market curves out to July 2020. Extended to 2035 by escalating both gas and power at 4% from July 2020 on.
Economically Optimal	Same as Current plus Market	Current plus Market +308MW CCCT +10x18MW ICEs +80 MW Frame CT	Same as Current plus Market	Same as Current plus Market	Same as Current plus Market
Preferred with Frame CT substituted for Wartsilas in 2019	Same as Current plus Market	Economically Optimal -4x18MW ICEs +80MW Frame CT	Same as Current plus Market	Same as Current plus Market	Same as Current plus Market
Low Load Growth	Same as Current plus Market	Economically Optimal -80MW Frame CT	Grows by ~0.4%/year (50% of Base Case)	Same as Current plus Market	Same as Current plus Market
High Load Growth	Same as Current plus Market	Economically Optimal +2x80MW Frame CTs	Grows by ~1.2%/year (150% of Base Case)	Same as Current plus Market	Same as Current plus Market
Low Carbon	Same as Current plus Market	Economically Optimal	Same as Current plus Market	Zero Carbon Costs	Same as Current plus Market
High Carbon	Same as Current plus Market	Economically Optimal	Same as Current plus Market	Carbon Cost = Maximum of Base Case triangular distribution	Same as Current plus Market
High Gas and Power Market	Same as Current plus Market	Economically Optimal	Same as Current plus Market	Same as Current plus Market	Natural Gas and Electric Prices increased by 22% over Base Case
Double Wind & Solar	Same as Current plus Market	Current plus Market +18x18MW ICEs +5x80 MW Frame CT	Same as Current plus Market	Same as Current plus Market	Same as Current plus Market
Triple Wind & Solar	Same as Current plus Market	Current plus Market +16x18MW ICEs +6x80 MW Frame CT	Same as Current plus Market	Same as Current plus Market	Same as Current plus Market
RPS Compliance	Same as Current plus Market	Economically Optimal	Same as Current plus Market	Same as Current plus Market	Same as Current plus Market

The EOP portfolio includes the all of the assumptions in the Current plus Market portfolio, but adds resources to achieve resource adequacy in approximately ten years. PowerSimm Planner selected capacity resource additions from the resources listed in Figure 12-2.

In all resource portfolio scenarios a GE 7FA.05 CCCT is added in 2025. With a capacity of 308 MW plus an additional 40 MW of duct firing capacity, this unit rapidly and costeffectively addresses a majority of NorthWestern's capacity needs. PowerSimm Planner "fills in the corners" with a mix of more flexible ICEs and later frame CTs to meet NorthWestern's future capacity and flexibility requirements. Table 12-3 shows unit build-outs by portfolios and scenarios.

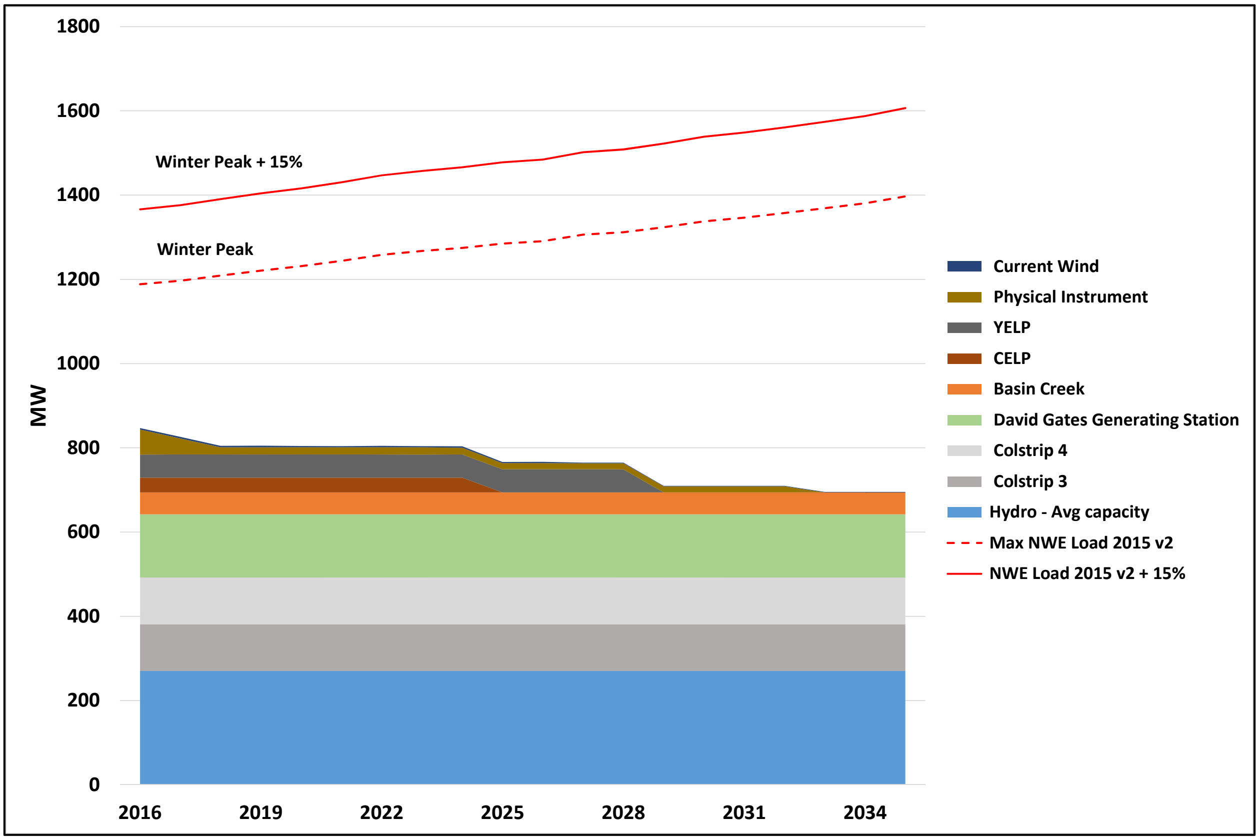
Table 12-3 Description of New Units by Portfolio

Portfolio	2016-2019	2020-2025	2026-2029	2030-2035
Current plus Market	No Additions	No Additions	No Additions	No Additions
Economically Optimal **High Carbon** **Low Carbon** **High Gas & Power**	3xICE	2xICE CCCT	5xICE 2xFrameCT	No Additions
Frame CT in 2019	FrameCT	2xICE CCCT	5xICE 2xFrameCT	No Additions
Low Load Growth	2xICE	ICE CCCT	6xICE FrameCT	No Additions
High Load Growth	4xICE	3xICE CCCT	3xICE 2xFrameCT	No Additions
RPS Compliance	3xICE	2xICE CCCT	5xICE 2xFrameCT	No Additions
Double Wind & Solar	2xICE 1xFrameCT	6xICE 2xFrameCT	10xICE 2x FrameCT	No Additions
Triple Wind & Solar	4xICE 2xFrameCT	12xICE 4xFrameCT	No Additions	No Additions

Capacity Expansion Charts

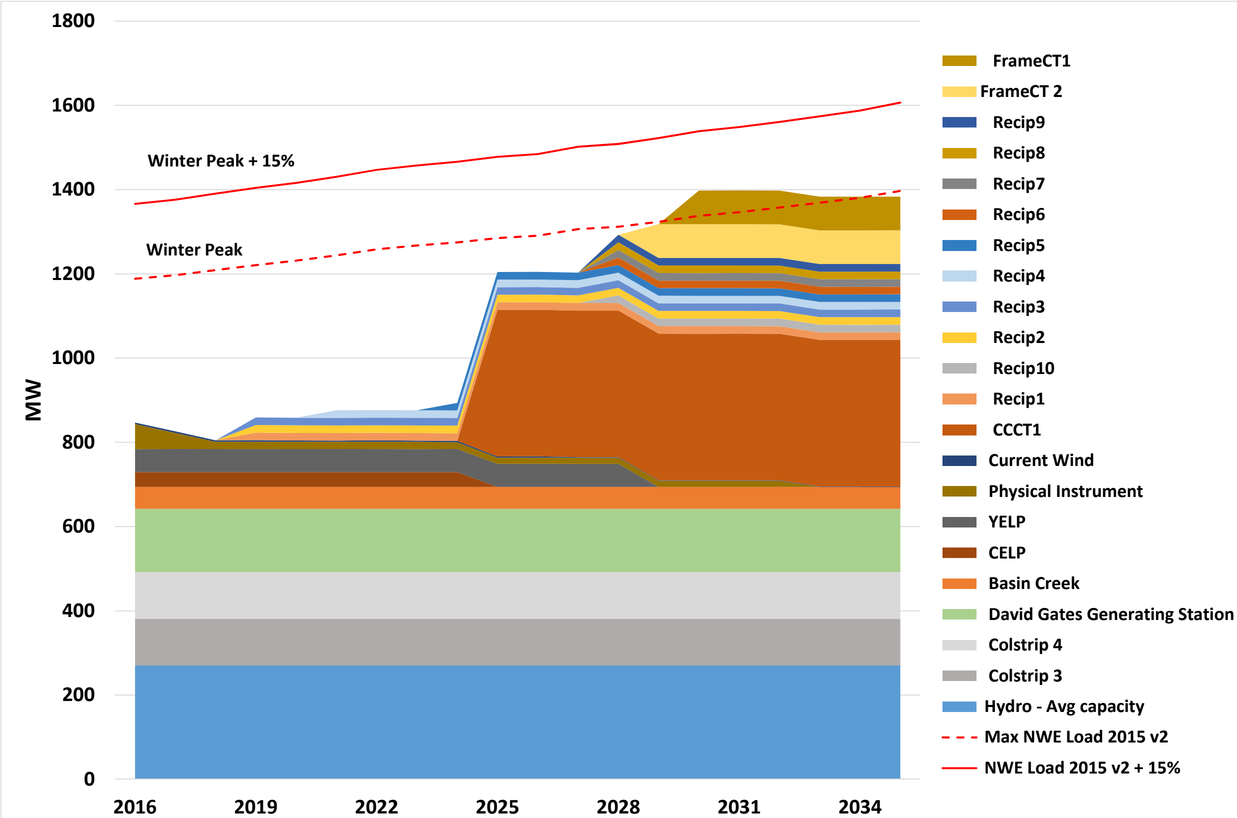
The following capacity expansion charts illustrate the growth in capacity over time of the Current plus Market and Preferred portfolios. Figure 12-1 shows the available winter capacity of all generation assets in NorthWestern's current resource portfolio. The dashed red line represents NorthWestern's winter peak demand forecast, while the solid red line represents winter peak demand plus a 15% reserve planning margin. The gap between the resource stack and the winter peak demand forecast represents NorthWestern's current resource adequacy deficit, which is substantial.

Figure 12-1 Current Plus Market Portfolio



The capacity expansion and resource adequacy of the EOP is shown in Figure 12-2. The EOP begins with the addition of three 18-MW ICEs in 2019 and continues to add a total of 10 ICEs by 2028. The flexibility of ICEs yields substantial value in a market that is short of flexible and fast ramping resources. The largest resource addition occurs in 2025 with a 348-MW CCCT (including 40 MW of duct firing). The CCCT plant substantially addresses NorthWestern's capacity deficit. The addition of two Frame CTs in 2028 and 2029 brings NorthWestern's reserve margin slightly above 100% physical resource adequacy, but still short of a minimal planning reserve margin.

Figure 12-2 EOP Capacity Expansion

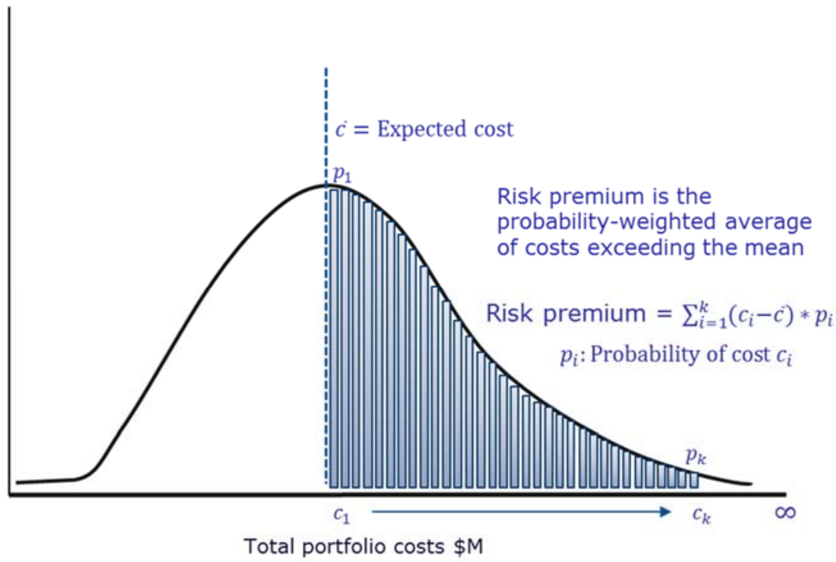


Valuation of Risk

PowerSimm dispatches NorthWestern's resources iteratively for all years of the study horizon in order to arrive at a distribution of future costs. The expected value of portfolio costs is therefore a robust metric to determine the cost ranking of the different portfolio options, but it does not capture the differences in risk between the portfolios. Given the substantial uncertainty in future prices of fuel, wholesale power costs, and carbon costs between portfolios, the distributions of costs around each portfolio's expected value are significantly different.

PowerSimm monetizes the difference in the shapes of these distributions by use of the *risk premium*, defined as the integral of the cost distribution above the mean. This is similar to the approach taken by traders to evaluate the value of an option, or by insurance companies in valuing a policy. The derivation of the risk premium is illustrated graphically in Figure 12-3 below.

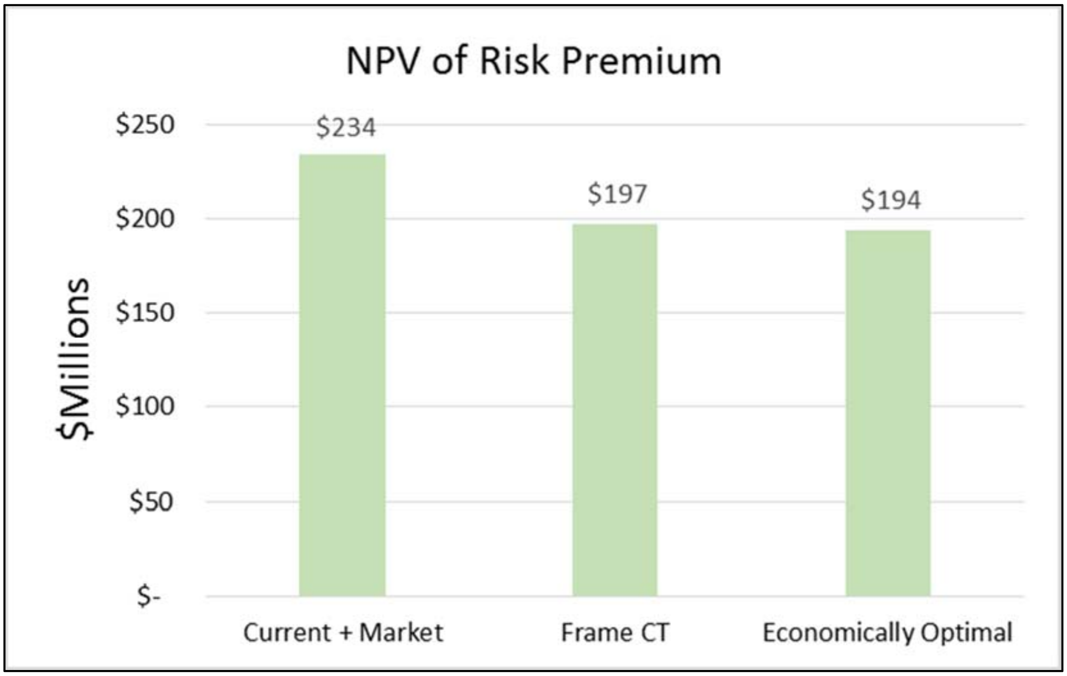
Figure 12-3 Illustration of Risk Premium Concept



The risk premium is added to the expected value to better approximate the full distribution of costs. This risk metric improves upon traditional planning approaches such as cost-at-risk or efficient frontier analysis by providing a single number by which to compare portfolios, rather than requiring a planner to decide on a weighting between cost and risk.

The risk premiums of annual levelized cost for select portfolio options are shown below in Table 12-4. The bars represent the risk premium calculated by applying the method shown above to total portfolio costs realized for different simulated future states. The Current + Market portfolio has a risk premium of $234 million, or 4% of total NPV of costs, versus $194 million (3.5% of NPV of costs) for the EOP and $197 million (3.6% of NPV of costs) for the Frame CT Portfolio. The difference between the risk premiums of Current + Market and the EOP, $40 million, is the NPV of the risk reduction value of the EOP. The risk value illustrates the monetary value of decreased uncertainty of future costs with the expansion plans.

Figure 12-4 Values of Risk Premium for Select Portfolios



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Net Present Value of Portfolio Costs

PowerSimm produces a NPV of the long-term costs of each portfolio. These costs are presented in Table 12-5 below, in terms of NPV. Total NPV is broken out into components of existing fixed and capital costs, variable costs and market, fixed and capital costs plus infrastructure costs less the residual value of new resources, and risk premium.

Table 12-4 Net Present Value of Portfolio Costs by Scenario and Category

Resource Portfolio	Total	Existing Fixed & Capital Costs	Generation Costs + Market Costs	New Fixed Capital and Infrastructure Costs	Risk Premium
Low Carbon Cost	$5,007 M	$2,797 M	$1,718 M	$407 M	$85 M
Low Load Growth	$5,323 M	$2,797 M	$2,033 M	$341 M	$181 M
Frame CT	$5,462 M	$2,797 M	$2,078 M	$391 M	$197 M
Economically Optimal	$5,482 M	$2,797 M	$2,085 M	$407 M	$194 M
High Gas & Power Prices	$5,549 M	$2,797 M	$2,144 M	$407 M	$202 M
High Load Growth	$5,624 M	$2,797 M	$2,170 M	$452 M	$204 M
High Carbon Cost	$5,720 M	$2,797 M	$2,378 M	$407 M	$138 M
Current plus Market	$5,944 M	$2,797 M	$2,913 M	$0 M	$234 M
Double Wind and Solar	$5,957 M	$2,797 M	$2,152 M	$839 M	$170 M
RPS Compliance	$6,146 M	$2,797 M	$2,648 M	$537 M	$163 M
Triple Wind and Solar	$6,340 M	$2,797 M	$2,084 M	$1,300 M	$159 M

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Figure 12-5 Net Present Value of Portfolio Costs Plus Carbon Footprint

Figure 12-5 is a graphical illustration showing the NPV of all portfolio model runs and cost components: existing fixed and capital costs, variable costs and market, fixed and capital costs plus infrastructure costs less the residual value of new resources and risk premium. A comparison of carbon emissions rates is also included. Carbon emissions rates are addressed in greater detail at the end of this chapter. Comparisons between groups of portfolios follow.

Figure 12-6 shows a graphical representation of the costs of the Current plus Market, the EOP, and the EOP plus Frame CT portfolios. The Frame CT portfolio is the same as the EOP, but with a frame CT substituted for the ICEs in 2019. The Frame CT portfolio is included to illustrate the difference in technology cost only. The substitution of Frame CT for ICE technology as a near-term resource choice achieves lower cost but does not achieve needed resource flexibility capability of the ICE.

Figure 12-6 Net Present Value Costs of Current + Market, Frame CT, and EOP

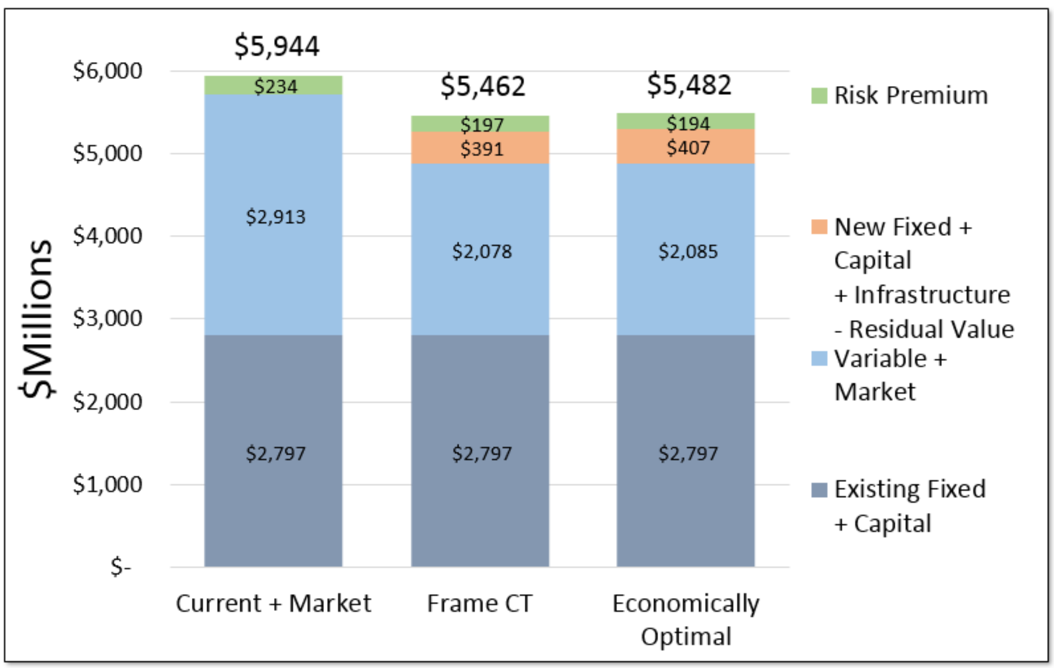

Figure 12-7 below is a similar illustration but compares the EOP to Low Load Growth and High Load Growth. As shown in Table 12-2 above, loads grow at 0.4% per year in the Low Growth portfolio, 1.2% per year in the High Growth portfolio, and at 0.8% per year in all other portfolios.

Figure 12-7 Net Present Value Cost of EOP Under Alternative Load Growth Scenarios

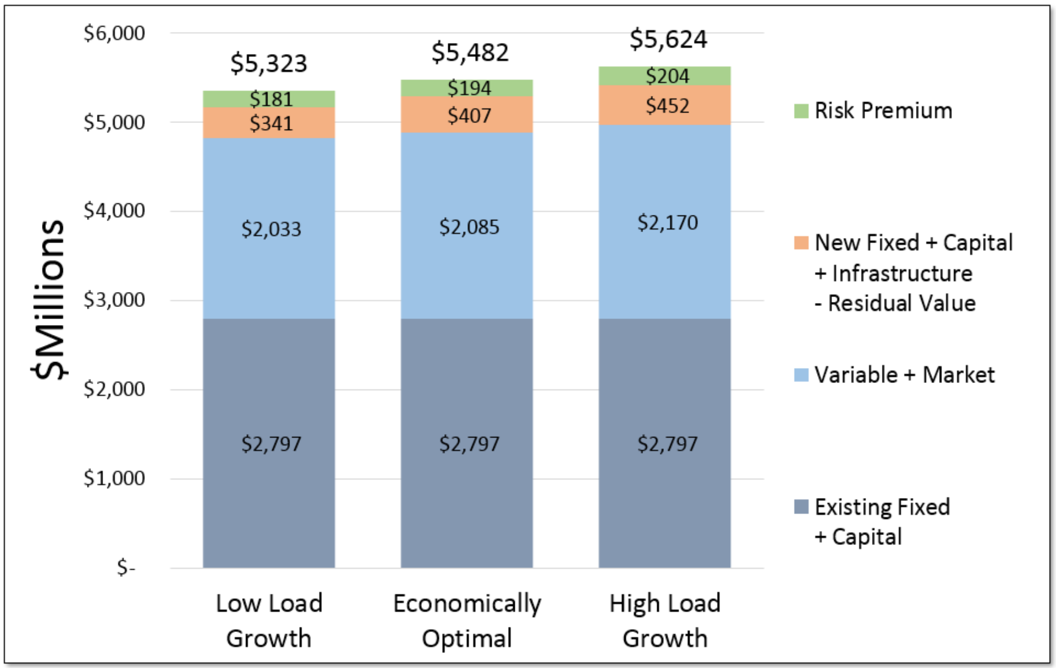

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Figure 12-8 below shows the NPV of the EOP under alternate price sensitivities: High Carbon Cost, Low Carbon Cost, and "High Gas and Power". As described earlier, the Low Carbon Cost portfolio assigns no cost to carbon, and the High Carbon Cost portfolio assigns a carbon cost of $40/ton. The High Gas and Power portfolio increases natural gas and wholesale electric power prices by 22%, while maintaining the pricing relationships (heat rate) established in the Current plus Market portfolio.

Figure 12-8 Net Present Value Cost of EOP Price Sensitivities

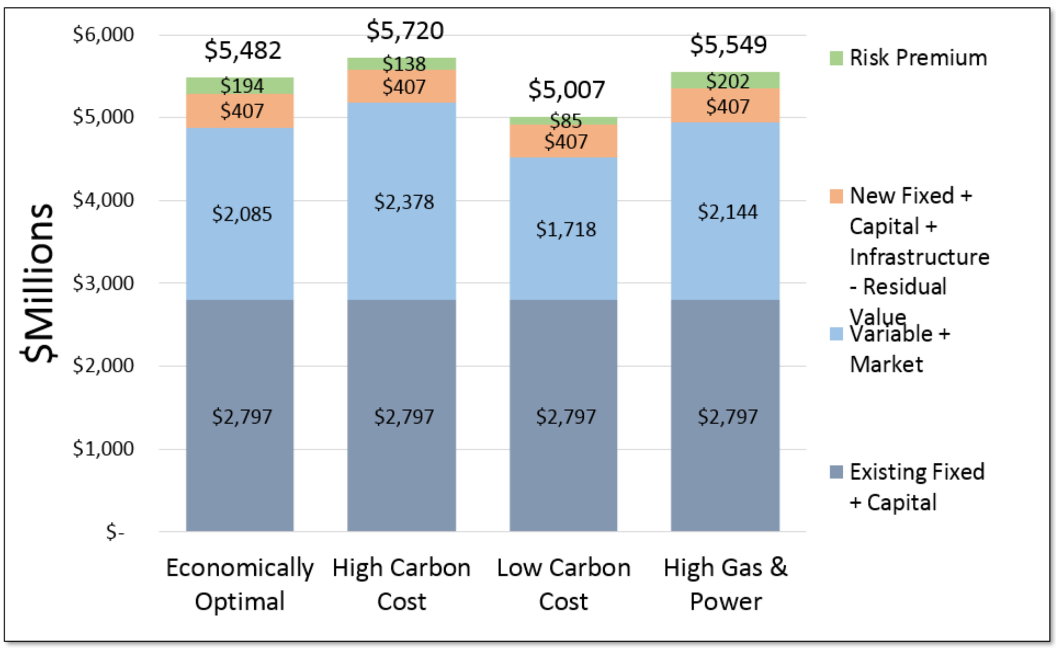

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Figure 12-9 shows the NPV of the EOP and three portfolios in which additional wind and solar PV are forced into the model. The RPS Compliance portfolio assumes company ownership of all wind resources needed to meet NorthWestern's RPS requirement through the 20-year planning horizon. The second portfolio, Double Wind & Solar, nearly "doubles" NorthWestern's current portfolio of wind and solar PV, adding 224 MW of wind and 24 MW of solar PV. The third portfolio, Triple Wind & Solar, nearly "triples" the current portfolio of wind and Solar PV, adding 448 MW of wind and 42 MW of solar PV.

The Double Wind & Solar portfolio and the Triple Wind & Solar portfolio are based off the Current plus Market portfolio. However, flexible gas-fired resources are added to each portfolio to meet ancillary service requirements and also to meet minimal resource adequacy in approximately ten years. The three portfolios meet the same capacity adequacy standard as the EOP so all four portfolios are comparable.

NorthWestern has limited transportation ability to export excess energy to sell to counterparties. The inclusion of the additional wind and solar resources generates significant surplus energy, so much so that NorthWestern would have challenges selling surplus energy in a market that is already long energy. To account for this, NorthWestern models surplus energy in the following manner: Surplus sales up to 20% of load receive market price; all remaining sales receive only 20% of the market price.

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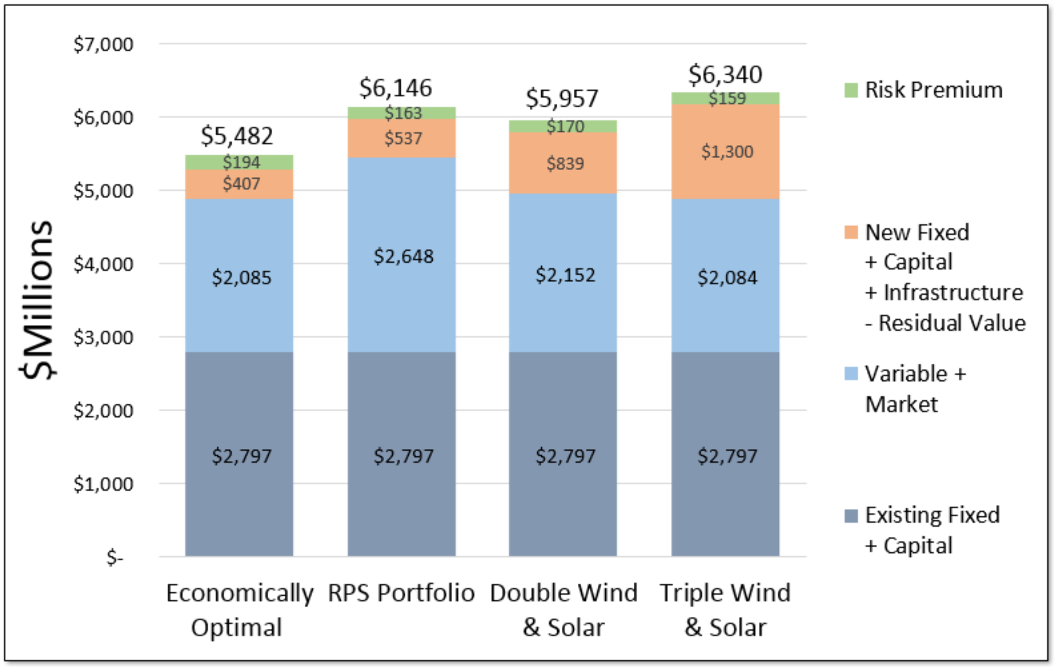
Figure 12-9 Net Present Value Cost of EOP, and EOP with Additional Wind



Carbon Footprint

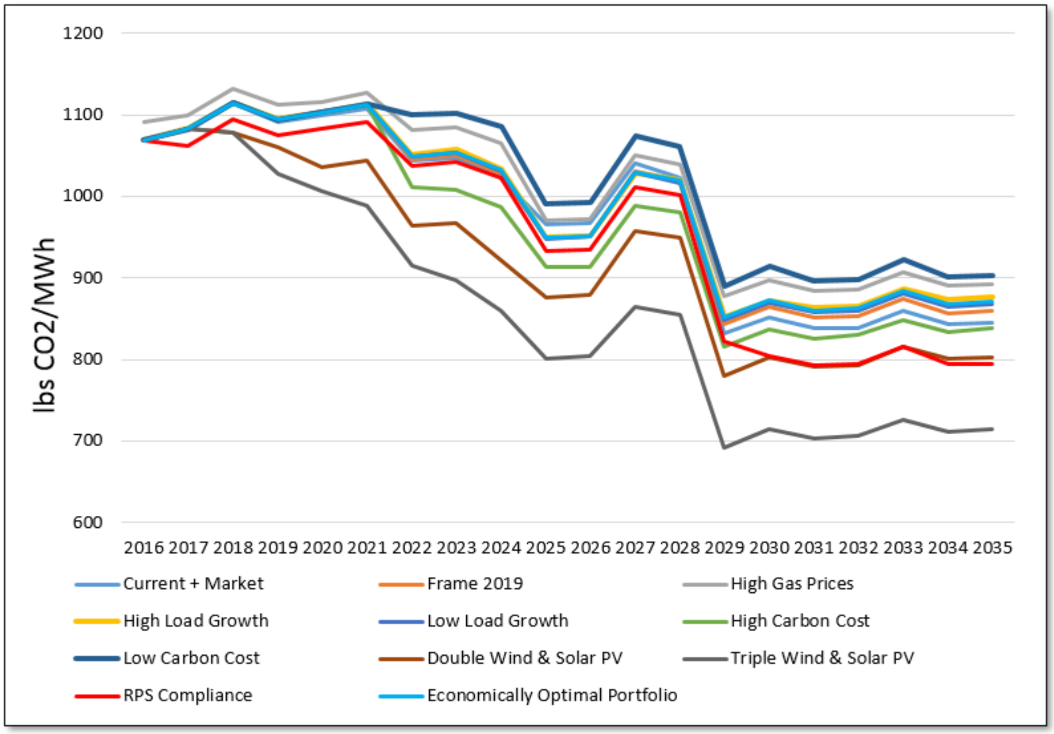
Table 12-5 shows carbon emissions rates for each resource portfolio, and Figure 12-10 shows carbon emissions rates for each resource portfolio over the 20-year planning horizon. All resource portfolios have relatively low carbon emissions; all are under 1,000 lbs./MWh except for the Low Carbon Cost and High Gas Cost portfolios. As expected, the Low Carbon Cost portfolio has the highest rate of carbon emissions, while the Triple Wind & Solar portfolio has the lowest carbon emissions. The EOP is a relatively low carbon emission portfolio while achieving minimal resource adequacy in approximately ten years. However, the EOP does not meet NorthWestern's current RPS obligation. The RPS Compliance portfolio meets NorthWestern's goals of meeting minimal resource adequacy in approximately ten years at lowest cost and meeting NorthWestern's future 15% RPS obligations. It also achieves the second lowest carbon footprint by the end of the planning horizon.

Table 12-5 Carbon Footprint (20-Year Average Annual)

Portfolio	Average Annual (lbs/MWh)	Percent of Current + Market
Low Carbon Cost	1,015	103.7%
High Gas Prices	1,009	103.0%
High Load Growth	988	100.9%
Economically Optimal	986	100.8%
Low Load Growth	985	100.6%
Frame CT	982	100.3%
Current + Market	979	100.0%
High Carbon Cost	960	98.1%
RPS Compliance	954	97.4%
Double Wind & Solar PV	924	94.3%
Triple Wind & Solar PV	861	87.9%

The variations in carbon emissions rates shown in Figure 12-9 occur because NorthWestern assumes all resources drop out of the resource portfolio after their contracts expire. The CELP contract expires in 2024, the Judith Gap wind energy PPA contract expires at the end of 2026, and the YELP contract expires at the end of 2028. These expiring contracts have a significant impact on the portfolio's estimated carbon emissions.

Figure 12-10 Carbon Emission Rates by Portfolio
(lbs CO2/MWh)



Conclusions

The EOP meets minimum resource adequacy and incorporates the co-optimization of hydroelectric and thermal resources to achieve low-cost and efficient generation operations. Resources including DGGS, Basin Creek, and Colstrip will be used in both load-serving and ancillary services roles. DGGS will no longer be used exclusively as a regulation service resource, but will also be used to provide contingency reserves and load-following services, and to provide peaking capacity at times of peak demand.

The EOP provides a least-cost and least-risk mix of resources needed to meet the capacity and ancillary service needs associated with loads and generation. However, NorthWestern must also comply with RPS. Therefore, RPS requirements are forced into the EOP in the RPS Compliance portfolio, albeit at higher NPV cost.