# Net Energy Metering (NEM) Benefit-Cost Analysis

**Prepared for:**

**NorthWestern Energy – Montana**

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# LIST OF ACROYNMS

| | |
|---|---|
| ADMS | Advanced Distribution Management System |
| AGC | Automatic Generation Control |
| BA | Balancing Area |
| BAU | Business-as-usual |
| $CO_2$ | Carbon Dioxide |
| DERMS | Distributed Energy Resources Management System |
| ELCC | Effective Load Carrying Capacity |
| GDP | Gross Domestic Product |
| GIS | Geographic Information System |
| IT | Information Technology |
| kW | Kilowatt |
| kWh | Kilowatt-hour |
| MPSC | Montana Public Service Commission |
| MW | Megawatt |
| NARUC | National Association of Regulatory Utility Commissioners |
| NEM | Net Energy Metering |
| NERC | North American Electric Reliability Corporation |
| NREL | National Renewable Energy Laboratory |
| NWPP | Northwest Power Pool |
| O&M | Operations & Maintenance |
| OT | Operational Technologies |
| POM | Portfolio Optimization Model |
| PV | Photovoltaic |
| QF | Qualifying Facilities |
| RBC | Reliability Based Control |
| REC | Renewable Energy Credit |
| RIM | Ratepayer Impact Measure |
| ROI | Return on Investment |
| RPS | Renewable Portfolio Standard |
| SCADA | Supervisory Control and Data Acquisition |
| T&D | Transmission & Distribution |
| UCT | Utility Cost Test |
| US | United States |
| VER | Variable Energy Resource |
| VOS | Value of Service |
| WACC | Weighted Average Cost of Capital |
| WECC | Western Electricity Coordinating Council |

# 1. INTRODUCTION

## 1.1 Background

Navigant was retained by NorthWestern Energy (NorthWestern) to conduct an economic analysis and evaluation of solar photovoltaic (PV) net energy metering (NEM) benefits and costs in the State of Montana in response to House Bill 219, passed by the Montana Legislature in April 2017 and signed by the Governor of Montana on May 3, 2017. NorthWestern is required to conduct and submit to the Montana Public Service Commission (MPSC) a NEM study of the costs and benefits of customer-generators before April 1, 2018. The results of Navigant's NEM study complies with the law, and could support the development of a new rate class for NEM solar if the results of the study justify the need to create a separate NEM rate class.

## 1.2 Study Objectives

This NEM study focuses on developing utility system benefits and costs of solar PV NEM resources over a 25-year analysis period, years 2018 through 2042. Specifically, Navigant's study evaluates customer-generators with behind-the-meter solar PV rated up to 50 kW within NorthWestern's Montana electric service territory. The benefits and costs derived in the study are based on the categories outlined in the Minimum Information Requirements in Attachment 1 of the MPSC Notice of Commission Action (MPSC Notice) dated August 9, 2017. [1] Navigant compared this list to the benefit and cost categories outlined in the National Association of Regulatory Utility Commissions (NARUC) Manual on Distributed Energy Resources Rate Design and Compensation[2] and believes these categories identified in the MPSC Notice are reasonable and sufficient for the purposes of a net metering study. All costs and benefits in this study are derived using 25-year levelized values.

[1] Montana Public Service Commission (MPSC) Docket No. D2017.6.49; http://psc.mt.gov/Docs/ElectronicDocuments/pdfFiles/D2017649NCA.pdf.

[2] Staff Committee on Rate Design, *Manual on Distributed Energy Resources Rate Design and Compensation*, National Association of Regulatory Utility Commissions, 2016.

# 2. APPROACH

This section outlines Navigant's approach to conducting the NEM study. It presents the rationale and sources the Navigant team[3] relied on to derive marginal benefits and costs for each category outlined in the MPSC Notice. Navigant's approach generally erred on the side of ensuring a higher level of solar benefits; however we consider the range of uncertainty on the results presented in this report to be fairly narrow. The team's approach recognized location-based factors outlined in the MPSC Notice, and incorporated these factors for certain benefit categories. The applied methodology for certain benefit and cost streams was informed by NorthWestern's discussions with the Electric Technical Advisory Committee as required in the MPSC Notice.

## 2.1 Solar Adoption Scenarios

The MPSC engaged the National Renewable Energy Laboratory (NREL) in late 2017 to prepare a detailed 25-year forecast of NEM solar potential within NorthWestern's Montana service territory.[4] Navigant relied on the results of the NREL study to develop three solar adoption scenarios for the NEM study, summarized in Table 1. These projections include an annual degradation factor of 0.5% over the analysis period to account for loss of solar panel efficiency.

**Table 1. Solar PV Adoption Scenarios (Net MW)**

| Year | Low | Medium | High |
|---|---|---|---|
| 2018 | 16.4 | 18.9 | 21.5 |
| 2019 | 22.1 | 31.2 | 40.4 |
| 2020 | 28.9 | 47.1 | 65.2 |
| 2021 | 36.5 | 66.8 | 97.1 |
| 2022 | 45.2 | 88.0 | 130.7 |
| 2023 | 55.1 | 108.2 | 161.3 |
| 2024 | 66.5 | 127.7 | 188.9 |
| 2025 | 80.2 | 146.0 | 211.8 |
| 2026 | 95.3 | 163.3 | 231.3 |
| 2027 | 112.2 | 180.2 | 248.3 |
| 2028 | 128.7 | 195.5 | 262.4 |
| 2029 | 142.4 | 207.6 | 272.8 |
| 2030 | 154.8 | 217.9 | 280.9 |
| 2031 | 166.7 | 227.3 | 287.8 |
| 2032 | 177.4 | 235.6 | 293.8 |
| 2033 | 186.2 | 242.7 | 299.3 |
| 2034 | 193.3 | 249.0 | 304.7 |
| 2035 | 198.5 | 254.4 | 310.2 |

[3] Throughout this report, all references to "the team" refers to the Navigant team.

[4] Paritosh Das, Kevin McCabe, Pieter Gagnon. *Projections of Behind-the-Meter Photovoltaic Adoption in NorthWestern Energy's Montana Service Territory through 2050*, https://www.nrel.gov/docs/fy18osti/70696.pdf.

| Year | Low | Medium | High |
|---|---|---|---|
| 2036 | 202.6 | 259.4 | 316.1 |
| 2037 | 206.3 | 264.5 | 322.8 |
| 2038 | 209.3 | 269.7 | 330.1 |
| 2039 | 211.6 | 275.0 | 338.4 |
| 2040 | 213.6 | 280.0 | 346.4 |
| 2041 | 215.4 | 284.0 | 352.6 |
| 2042 | 217.0 | 287.7 | 358.3 |

*Source: Navigant analysis*

To derive the forecasts in Table 1, Navigant adjusted NREL's results[5] to ensure that the forecasts were realistic in the context of its study. NREL's study applies a modeling framework that predicts market adoption as a function of customer economics (i.e., the payback period for customers to obtain a net-positive return on their investment in solar). NREL makes various assumptions that lead to advantageous participating customer economics (e.g., full retail rate for excess energy, omission of PV system financing costs and eligibility factors), therefore predicting a high level of adoption. Furthermore, at the solar adoption levels predicted for NREL's Central, Central+, Favorable, and Favorable+ forecasts, Navigant expects that NorthWestern would encounter performance issues such as reverse power flow and thermal or voltage violations when midday load is low and solar output is high. To alleviate these impacts, NorthWestern would likely be required to make various distribution system upgrades, thereby reducing the net benefit that solar provides to the grid. Applying this reverse power threshold on NEM solar avoids the cost of mitigating reverse power and performance violations.[6] Navigant expects that as solar penetration levels increase in the later years the NEM retail rate will decline due to a reduction in the net benefits.[7]

Navigant developed a more realistic high forecast for its study where NEM solar adoption at each substation is based on a reverse power flow threshold. This derivation of the reverse power threshold is based on a substation-level analysis of minimum load to set the maximum limit of NEM in 2042 (i.e., the last year of the analysis period). Navigant then scaled the solar forecast in all other years based on NREL's Central+ adoption forecast. For its low forecast, Navigant used NREL's Unfavorable forecast of solar adoption adjusted for degradation. For the medium forecast, Navigant averaged its low and high forecasts.

## 2.2 Solar Profiles

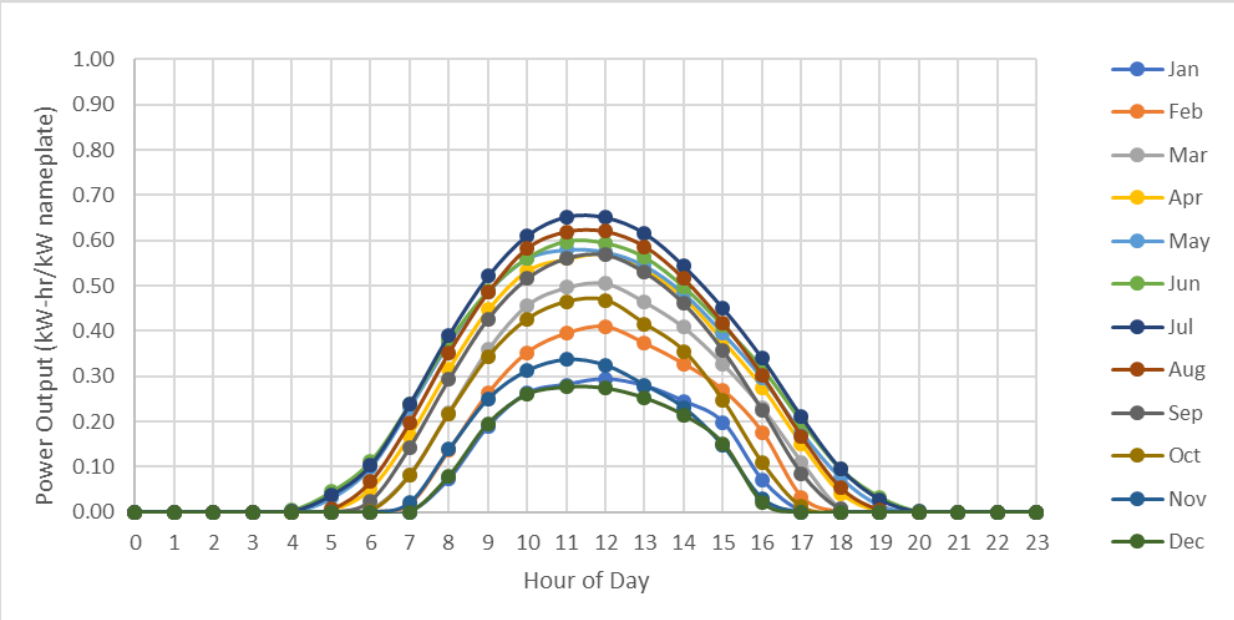
Navigant utilized the same solar production shape methodology used in NREL's study which based the solar production shape on a weighted mixture of rooftop orientations and locations of the entire fleet of systems in 2018. The team then applied an annual degradation factor of 0.5% to forecast the production shape based on the number of years each system is in place. The average undegraded shape by hour of day and month is shown in Figure 1.

[5] NREL's study reported six different adoption forecasts: Unfavorable, Unfavorable+, Central, Central+, Favorable, and Favorable+.

[6] Because Navigant constrained NEM solar capacity forecasts to avoid mitigation costs, the interconnection and integration cost components in Sections 2.6.3 and 2.6.4 are set at zero.

[7] For example, in Arizona, the commission decided to reduce the export rate for excess solar generation to a flat rate that converges over time towards actual avoided costs which were lower than the retail rate. See: https://www.aps.com/library/rates/RCP.pdf

**Figure 1. PV Production Shape by Hour of Day and Month**




*Source: Navigant Analysis of National Renewable Energy Lab Data*

## 2.3 Financial Parameters

Navigant applied a 7.03% nominal discount rate[8] for all present value calculations for the utility cost test (UCT) and ratepayer impact measurement (RIM) tests based on NorthWestern's approved weighted average cost of capital (WACC). Navigant recognizes MPSC's recommendation in the MPSC Notice to consider the long-term, risk-free rate in addition to NorthWestern's own marginal cost of capital; however, the team applied the commission-approved discount rate for consistency with NorthWestern's recent avoided cost and other filings. To forecast future prices, Navigant applied a 2% inflation rate based on the 20-year average inflation escalation for GDP provided by the US Bureau of Economic Analysis.

## 2.4 Benefit-Cost Analysis Framework

Navigant created a model that calculates the net present value of benefits and costs of NEM from two cost test perspectives:

1. **Utility Cost Test (UCT):** This test calculates the benefits and costs from NorthWestern's perspective. The resulting net present value from this cost test can be used to quantify the net benefits that NEM provides to the utility and can help set a value-based rate at which customers are paid for their excess energy.
2. **Ratepayer Impact Measure (RIM) Test:** This test calculates the benefits from the customers' perspective and therefore can be interpreted as a customer impact test. The resulting net present value from this cost test is often used to inform whether the amount paid or credited to the solar owner exceeds the net benefits from NEM realized by the utility. If the net present value is

[8] From MPSC Notice: "NWE should use scenarios which use the long-term risk-free rate and also its own marginal cost of capital as proxies for a reasonable discount rate."

negative, it can be inferred that non-participants are subsidizing the participants. Contrarily, if the net present value is positive, it can be inferred that participants are subsidizing the non-participants. Under either condition, it may be appropriate to form a new rate class for NEM solar customers.

The definitions of these cost tests are in accordance with the California Public Utilities Commission California Standard Practice Manual,[9] by applying the cost-effectiveness framework outlined in Table 2.

**Table 2. Cost Test Definitions**

| Value Stream | UCT | RIM |
|---|---|---|
| Avoided Energy Costs | Benefit | Benefit |
| Avoided Capacity Costs | Benefit | Benefit |
| Avoided Transmission and Distribution Capacity Costs | Benefit | Benefit |
| Avoided System Losses | Benefit | Benefit |
| Avoided RPS Compliance Costs | Benefit | Benefit |
| Avoided Environmental Compliance Costs | Benefit | Benefit |
| Market Price Suppression Effects (Fuel Hedging) | Benefit | Benefit |
| Avoided Risk (e.g., reduced price volatility) | Benefit | Benefit |
| Avoided Grid Support Services Costs | Benefit | Benefit |
| Avoided Outages Costs | Benefit | Benefit |
| Non-Energy Benefits | Benefit | Benefit |
| Reduced Revenue | N/A | Cost |
| Administrative Costs | Cost | Cost |
| Interconnection Costs | Cost | Cost |
| Integration Costs | Cost | Cost |

*Source: Navigant*

For the three solar adoption scenarios, Navigant calculated a nominal cash flow of each value stream over a 25-year analysis period (2018-2042). The team then calculated a 25-year levelized value of solar in dollars per kilowatt-hour for each cost test based on the levelization methodology described in Appendix B.

## 2.5 Benefit Calculation Methodologies

This section provides the definition of each benefit stream and Navigant's approach to quantifying these values. Navigant evaluated benefit categories that align with those outlined in Attachment 1 to the MPSC Notice. The methodology is also consistent with the descriptions outlined in the MPSC Notice, which the team applied to derive values in each category. To the extent possible, Navigant sought to derive marginal benefits (and costs in Section 2.6) based on NorthWestern data and resource plans versus reliance on industry averages and proxy data.

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[9] California Public Utilities Commission, *California Standard Practice Manual: Analysis of Demand-Side Programs and Projects*, http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/Utilities_and_Industries/Energy_-_Electricity_and_Natural_Gas/CPUC_STANDARD_PRACTICE_MANUAL.pdf.

### 2.5.1 Avoided Energy Costs

Previous Navigant NEM studies indicate that benefits associated with avoided energy production typically constitute the majority of avoided costs associated with solar NEM. Hence, Navigant carefully reviewed and vetted the assumptions and methods used to derive long-term avoided energy costs. Further, the team's marginal energy cost forecast is based on the preferred MPSC-accepted methodology for estimating avoided energy costs for Qualifying Facilities (QF). Navigant applied avoided energy costs derived via NorthWestern using PowerSimm™[10] production cost simulation software.

The PowerSimm production cost analysis was used to derive avoided fuel, startup, and variable operations and maintenance (O&M) associated with seasonal variations in resource output using adjustments[11] to NorthWestern's most recent resource plan and assumptions. Navigant independently developed 25-year carbon price forecasts (details in Appendix A) for NorthWestern's generating units. The team derived avoided energy costs based on the difference in energy costs for the three solar scenarios (i.e., high, medium, and low forecasts) and the business-as-usual (BAU) case with and without carbon pricing. For each of the solar scenarios, avoided energy costs were calculated by comparing the difference in total production (energy) costs from PowerSimm for each solar forecast to the BAU case. The difference in total energy cost divided by net solar output represents the costs avoided by NEM solar.

Table 3 summarizes the 25-year levelized avoided energy costs value by solar adoption forecast and $CO_2$ price forecast.

**Table 3. Levelized Avoided Energy Costs (25-Year)**

| Solar NEM Scenario | Total Benefit: 25-Year Levelized ($/kWh) |
|---|---|
| Low Forecast, $CO_2$ Included | $0.032 |
| Medium Forecast, $CO_2$ Included | $0.031 |
| High Forecast, $CO_2$ Included | $0.030 |
| Low Forecast, $CO_2$ Excluded | $0.030 |
| Medium Forecast, $CO_2$ Excluded | $0.029 |
| High Forecast, $CO_2$ Excluded | $0.029 |

*Source: Navigant*

### 2.5.2 Avoided Capacity Costs

Avoided capacity costs are defined as the value of the deferral or avoidance of capacity purchases or investments due to the reduction in balancing area (BA) demand net of firm[12] solar capacity.

[10] PowerSimm™ is a production cost modeling software by Ascend Analytics (http://www.ascendanalytics.com/powersimm-planner.html).

[11] Adjustments were made to the forward price curves, known changes in resource portfolio, analysis horizon, and carbon pricing.

[12] For capacity-related avoided costs discussed in this report (i.e., avoided capacity costs, avoided T&D capacity costs), Navigant defines "firm solar capacity" as capacity-equivalent solar capacity trued up for line losses, adjusted for system coincidence, and adjusted for variable power output (e.g., changes in hourly solar output). This is distinguished from "nameplate solar capacity" which is the instantaneous maximum output of a solar PV system.

Navigant applied an annual average 6.1% capacity contribution factor to convert the solar nameplate capacity from behind-the-meter to firm capacity at the bulk system level (i.e., NorthWestern's BA). This factor was derived by NorthWestern using Southwest Power Pool's net planning capability calculation tool based on 10 years of QF solar and Montana retail load data, and that was approved by the MPSC in NorthWestern's last QF-1 docket.[13] Navigant reviewed this methodology and believes it provides a reasonable estimation of equivalent load carrying capability (ELCC) for NEM solar within NorthWestern's Montana service territory.[14]

To monetize the marginal value of firm solar capacity, Navigant used a levelized avoided cost of capacity corresponding with a 25-year net present value obtained from NorthWestern's recent QF-1 filing. Because NorthWestern currently has capacity deficits, avoided capacity costs occur in the early years of the study.

Table 4 summarizes the 25-year levelized avoided capacity costs value by solar adoption forecast scenario.

**Table 4. Levelized Avoided Capacity Costs (25-Year)**

| Solar NEM Scenario | Total Benefit: 25-Year Levelized ($/annualized kWh) |
|---|---|
| Low Forecast | $0.005 |
| Medium Forecast | $0.005 |
| High Forecast | $0.005 |

*Source: Navigant*

### *2.5.3 Avoided Transmission and Distribution Capacity Costs*

For transmission and distribution (T&D) benefits, Navigant derived avoided costs based on detailed marginal cost information that it was able to obtain from NorthWestern's resource plans and budgets for capacity-based investments. Navigant assigned T&D benefits based on locational factors, including site-specific capacity additions that can reasonably be deferred (i.e., postponed) by firm NEM solar capacity. The team applied criteria that properly accounts for the amount of solar that is projected to be installed at specific locations on NorthWestern's distribution system and the timing of specific planned T&D capacity additions. This methodology is more rigorous and accurate than high level approaches, such as regression methods cited in Attachment 1 of the MPSC Notice. Similar to generation capacity contribution, there must be sufficient firm renewable capacity available along with adequate margins to defer a proposed T&D addition. The timeframe for which a capacity addition may be deferred is one or more years, which recognizes that load may grow more rapidly than the adoption of firm solar capacity at some substations.

#### *2.5.3.1 Avoided Distribution Capacity Costs*

Navigant derived avoided distribution capacity costs by projecting the amount of firm solar capacity that will be installed at NorthWestern's distribution substations, and then determined whether this firm capacity would be sufficient to defer capacity investments at these substations at any point over the next 25 years.

[13] MPSC Docket D2016.5.39

[14] In Section 3.3, Navigant recommends that NorthWestern conduct a study to update the capacity contribution value based on solar profiles from the National Renewable Energy Lab (NREL) studies cited herein and current load patterns for the NorthWestern system.

Navigant estimated the amount of NEM solar that will be installed at NorthWestern distribution feeders based on (1) the number of customers receiving service under NorthWestern's residential and general service rate classes (i.e., primary demand, primary non-demand, secondary demand, and secondary non-demand) at each substation, (2) an analysis of solar production's coincidence with substation-level peak, and (3) seasonality. The team's allocation approach assumes that all eligible NorthWestern customers are offered an equal opportunity to participate in the NEM solar program, and that the number of customers that elect to participate will occur at the same rate (i.e., in proportion) at each substation throughout NorthWestern's service territory.

The next step included a projection of when new substation capacity will be required over the next 25 years. Navigant obtained substation capacity ratings and compared these ratings to seasonal peak demands projected at each substation; NorthWestern provided demand forecast projections for each substation. If the amount of firm NEM solar capacity exceeded projected substation capacity deficits, solar was assigned a credit equal to the number of years that traditional capacity additions could be deferred multiplied by the assumed annual fixed cost of the traditional investment.

Navigant applied the following data and assumptions to determine the amount and value of deferring traditional substation capacity investments:

- Navigant applied a 52.1% and 0.0% seasonal capacity equivalence factor[15] for summer and winter, respectively, to estimate the capacity-equivalent solar capacity
- Navigant tracked NEM's forecasted effect on the winter and summer peak load to determine whether a particular substation is converted from summer-peaking to winter-peaking in the future due to the presence of solar
- A 3-year lead time to confirm that sufficient firm NEM solar will be available prior to the date when NorthWestern must make a go/no go decision on whether to proceed with the traditional solution
- A 10% margin to ensure sufficient NEM solar capacity is available in the event of higher than expected demand or less than expected solar output
- Cost of traditional substation capacity addition based on the size of existing substation capacity: $500,000 if less than or equal to 1 MW; $1.75 million if less than or equal to 5 MW, but greater than 1 MW; $8 million if less than or equal to 20 MW, but greater than 5 MW; $20 million if greater than 20 MW
- Levelized annual fixed carrying charge rate of 15% for substation capacity
- No benefits accrue beyond year 25

Table 5 presents Navigant's projections of the number of deferral instances and value of substation capacity deferred by NEM solar for each of the three scenarios evaluated in its study.

[15] Navigant derived these values based on NorthWestern's Southwest Power Pool (SPP) Renewable Net Capability Tool.

**Table 5. Substation Capacity Deferrals**

| Solar Adoption Forecast | Number of Deferrals | Total Number of Years of Deferral | Levelized Value of Deferrals ($/kWh) |
|---|---|---|---|
| Low | 6 | 13 | $0.002 |
| Medium | 6 | 16 | $0.002 |
| High | 6 | 18 | $0.002 |

*Source: Navigant analysis*

#### *2.5.3.2 Avoided Transmission Capacity Costs*

From prior studies, Navigant has determined that the opportunities for deferral of transmission capacity is limited, and for some systems, nonexistent. The reasons for the limited deferral opportunity include:

(1) The long lead time required for planning, permitting, equipment procurement, and construction;

(2) The large number of capacity projects that are required to meet North American Electric Reliability Corporation (NERC) reliability criteria;

(3) The small amount of firm solar capacity—firm solar additions range from about 20 MW to 25 MW by year 25—versus capacity deficits, particularly for single (n-1) or second contingency (n-2) events;[16]

(4) Transmission that is constructed to interconnect generation or enable economic transactions with utilities and third parties located in other BAs;

(5) The mismatch between the seasonal and hourly time of the transmission peak versus the hours when solar capacity would be available; and

(6) The relatively small number of transmission upgrades or additions that are based solely on capacity deficiencies (e.g., obsolescence, condition, operating requirements, and site-related factors such as clearances often are reasons why transmission upgrades are required).

Navigant reviewed NorthWestern's proposed transmission projects for the next 15 years, and determined that none of the projects projected for the first 10 years could be deferred by NEM solar capacity. Most projects were either not needed to address capacity deficits, or were needed because conditions or deficiencies driving the need for these upgrades are necessary before the date when sufficient firm solar capacity would be available to defer the investment. Beyond 10 years, Navigant estimated, at a high level, that a mid-level transmission investment (e.g., $10 million) could potentially be deferred for up to 3 years for each scenario based on the amount of firm NEM solar.[17] The team assumed the deferral would occur in year 15 (i.e., 2032). Table 6 summarizes the 25-year levelized avoided transmission costs value by solar adoption forecast.

[16] NorthWestern has adopted North American Electric Reliability Corporation (NERC) P0 through P6 convention for categorizing normal versus contingency loadings.

[17] Navigant cautions that the assumption for transmission deferral is based on high level estimates used for the purpose of developing NEM avoided costs. The value derived by the team should not be construed to apply to specific projects, including QF interconnection requests.

**Table 6. Levelized Avoided Transmission Costs (25-Year)**

| Solar NEM Scenario | Total Benefit: 25-Year Levelized ($/kWh) |
|---|---|
| Low Forecast | $0.001 |
| Medium Forecast | $0.001 |
| High Forecast | $0.000[18] |

*Source: Navigant*

Table 7 summarizes the 25-year levelized avoided T&D costs value (i.e., Table 5 + Table 6) by solar adoption forecast.

**Table 7. Levelized Avoided T&D Costs (25-Year)**

| Solar NEM Scenario | Total Benefit: 25-Year Levelized ($/kWh) |
|---|---|
| Low Forecast | $0.003 |
| Medium Forecast | $0.003 |
| High Forecast | $0.002 |

*Source: Navigant*

### *2.5.4 Avoided System Losses*

Navigant derived the avoided system losses value using 4.05% distribution system losses and 4.03% transmission system losses. The distribution losses were derived by NorthWestern based on a CYME-DIST[19] model of distribution substations serving various rural, urban, and combination circuits. The transmission losses are based on NorthWestern Montana's 1998 Transmission Loss Study. The approximately 8% value of combined T&D losses is consistent with or greater than values in NorthWestern's wholesale tariffs and avoided costs studies that Navigant has encountered in prior studies; therefore, Navigant deemed each of these loss percentages as reasonable.

Table 8 summarizes the 25-year levelized avoided losses value by solar adoption forecast and $CO_2$ price forecast scenario.

[18] This value rounds to zero, but is a non-zero value in the model

[19] CYME-DIST is an industry-standard distribution modeling software platform.

**Table 8. Levelized Avoided Losses (25-Year)**

| Solar NEM Scenario | Total Benefit: 25-Year Levelized ($/kWh) |
|---|---|
| Low Forecast, $CO_2$ Included | $0.003 |
| Medium Forecast, $CO_2$ Included | $0.002 |
| High Forecast, $CO_2$ Included | $0.002 |
| Low Forecast, $CO_2$ Excluded | $0.002 |
| Medium Forecast, $CO_2$ Excluded | $0.002 |
| High Forecast, $CO_2$ Excluded | $0.002 |

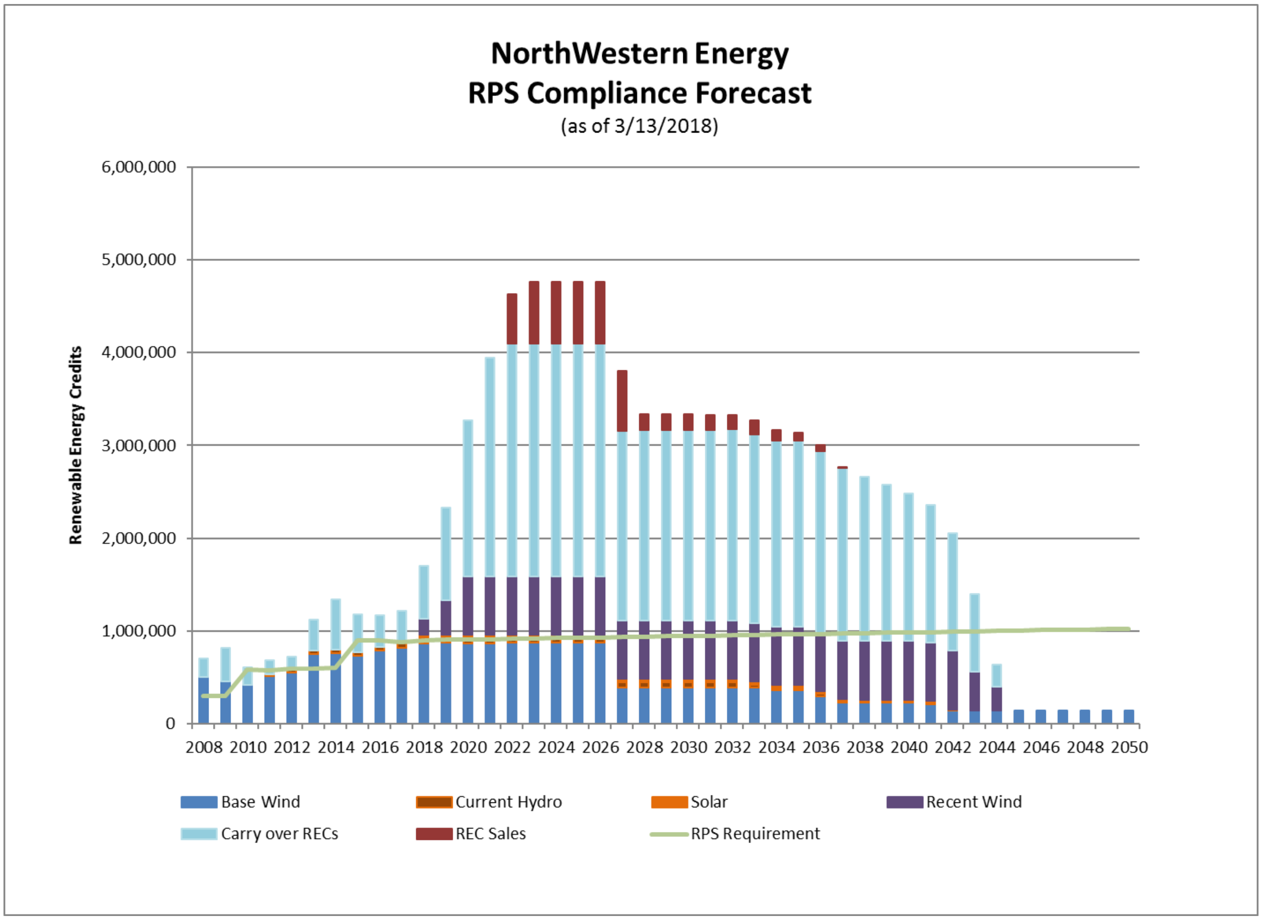
*Source: Navigant*

### *2.5.5 Avoided RPS Compliance Costs*

Avoided renewable portfolio standard (RPS) compliance costs represent the benefit associated with NEM's ability to assist NorthWestern in meeting its RPS compliance obligations. Navigant understands that Montana has a 15% RPS standard[20]. Based on Figure 2, Navigant determined that NorthWestern's RPS requirement is projected to be met by existing renewables, new wind energy, and carry-over renewable energy credits (RECs) through 2042. Accordingly, Navigant concluded that avoided RPS compliance costs or benefits associated with projected levels of NEM solar are zero.

[20] Montana Renewable Power Production and Rural Economic Development Act, § 69-3-2001

**Figure 2. NorthWestern Energy's RPS Compliance Forecast**




*Source: NorthWestern Energy*

### *2.5.6 Avoided Environmental Compliance Costs*

Navigant developed $CO_2$ price forecasts through 2042 for carbon pricing scenarios. The team applied methodology and assumptions to develop price forecasts, which are described in Appendix A. Compliance costs associated with sulfur oxides or nitrogen oxides, if any, are assumed to be embedded in the avoided energy costs as modeled in PowerSimm.

Navigant calculated the amount of displaced carbon from each solar adoption scenario using a forecast of average bulk system carbon emissions intensity values (pounds of $CO_2$ equivalent per megawatt-hour) derived from NorthWestern's 2015 Electricity Supply Procurement Plan. NorthWestern's avoided environmental compliance costs are the product of the annual amount of displaced $CO_2$ (in tons) by the carbon prices (in $/ton) listed in Table 15 of Appendix A.

Table 9 summarizes the 25-year levelized avoided environmental compliance costs value by solar adoption forecast for the $CO_2$ price forecast scenario.

**Table 9. Levelized Avoided Environmental Compliance Costs (25-Year)**

| Solar NEM Scenario | Total Benefit: 25-Year Levelized ($/kWh) |
|---|---|
| Low Forecast, $CO_2$ Included | $0.006 |
| Medium Forecast, $CO_2$ Included | $0.005 |
| High Forecast, $CO_2$ Included | $0.005 |

*Source: Navigant*

### *2.5.7 Market Price Suppression Effects (Fuel Hedging)*

Navigant believes that there will be a minimal price effect caused by the addition of solar PV into the regional energy and capacity markets. The adoption of solar NEM into NorthWestern's system is expected to be small in the medium adoption forecast with under 90 MW by 2022, and not increasing above 200 MW until 2029. This amount is small relative to the amount of regional capacity in the northwest. The Navigant team expects the level of adoption to have a small impact on market prices and fuel costs. In addition, NorthWestern is no longer participating in or engaged with fuel hedging activities. These two factors lead Navigant to conclude that benefits associated with market price suppression of fossil fuel are minimal and not applicable to NorthWestern.

### *2.5.8 Avoided Risk (E.g., Reduced Price Volatility)*

Similar to fuel hedging benefits, Navigant considers the premise that distributed solar would reduce price volatility to be unsupported for reasons cited in Section 2.5.7. Furthermore, the team's research indicates the benefits of avoided risk typically are not monetized in other value of solar studies (e.g., Lawrence Berkeley National Laboratory Study in California,[21] Clean Power Research Study in Minnesota,[22] South Carolina Office of Regulatory Staff[23]).

### *2.5.9 Avoided Grid Support Services Costs*

Navigant recently completed a study (variable energy resource or VER study) on behalf of NorthWestern to predict the amount of required load following and frequency regulation based on a recent update to NERC's reliability standard (also referred to as reliability based control or RBC), which has been adopted by the Western Electricity Coordination Council (WECC). The VER study was prepared to comply with an MPSC decision issued in 2012 that ordered NorthWestern to perform a study to evaluate the allocation of the regulation capacity needs.[24] Following the issuance of the MPSC Order, NERC adopted the RBC standard, which has significantly changed the way NorthWestern operates its generation resources to meet this new standard. NorthWestern in May 2016 adopted new procedures to comply with NERC's revised standard, which replaced the CPS1 and CPS2 standards that NorthWestern previously was obligated to meet. NorthWestern, similar to other utilities responsible for operating BAs, must ensure

[21] http://emp.lbl.gov/sites/all/files/lbnl-5445e.pdf

[22] http://mn.gov/commerce-stat/pdfs/vos-methodology.pdf

[23] http://www.regulatorystaff.sc.gov/Documents/Electric%20and%20Gas/DER%20and%20NEM%20Report%20-%20Final.pdf

[24] Order No. 6943e, Docket No. D2008.8.95.

generators it owns and operates and generators owned by third parties located within its BA, comply with NERC reliability rules.[25]

NEM solar is not a resource that is controllable from NorthWestern's system operations center, nor can be set on automatic generation control (AGC). Consequently, it is unable to provide any grid support services and therefore is assigned no benefit for grid support services. Further, because solar is a resource that operates intermittently, it likely requires grid support services to respond to rapid changes in output due to cloud cover. Navigant therefore designated NEM solar as a resource that produces negative benefits for Grid Support Services. This designation is similar to QF wholesale rate schedules that have been established for wind generation, which also operates intermittently.[26]

Because NorthWestern does not have NEM solar data that could be applied in the VER study to develop allocation factors for NEM solar resources, Navigant is unable to quantify the negative benefits for Grid Support Services. Until such data becomes available to enable NorthWestern to develop a NEM solar rate for Grid Support Services, Navigant recommends a negative benefit (i.e., cost) of zero.[27]

### *2.5.10 Avoided Outages Costs*

Navigant does not expect solar to have a material impact on NorthWestern's system reliability or avoided outage costs, particularly over the short-term. The amount of solar PV capacity forecast over the next 25 years will have minimal impact on the number and duration of interruptions on NorthWestern's transmission network and radial distribution feeders. Over the longer-term, with the introduction of smart technology, distribution SCADA, advanced inverter controls, and automated multi-feeder transfer capability, solar PV could have some effect on reducing the duration of outages. NorthWestern currently does not include in its plans the control systems and equipment required to accomplish the functions described above.

Another potential way for solar to provide avoided outage costs value is through the implementation of microgrids. NorthWestern has already implemented a microgrid pilot project to determine the potential benefits from solar integration within the microgrid system. However, NorthWestern does not have any future plans to implement additional microgrids onto its system at this time.

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[25]The RBC standard does not change NorthWestern's CPS1 requirements, but under prior rules the CPS2 standard has been replaced with new rules requiring BA operators to maintain Area Control Error (ACE) within regional BAAL limits for 30 consecutive minutes. The new 30-minute BAAL requirement has changed the way NorthWestern schedules generation to comply with the RBC standard. NorthWestern now tracks ACE relative to BAAL pre-assigned limits. If units that are automatic generation control (AGC)—typically David Gates Generating Station units—cannot maintain ACE within the BAAL deadband (i.e., ACE limits), the output of other generators not on AGC will be increased or decreased to bring ACE within the BAAL deadband. Alternatively, NorthWestern may start offline generators such as fast-start gas turbines or acquire resources from third-party suppliers to maintain ACE within BAAL limits.

[26] NorthWestern's Open Access Transmission Tariff Schedule 3 sets forth current terms and rates for third parties, generators, and customers who take Schedule 3 service are required to obtain frequency regulation and load following service.

[27] Navigant recognizes that NEM solar has different operating profiles than wind or large solar plants, and the allocation factors developed for the Generation class may not apply to NEM solar. Among other factors, NEM solar has greater locational diversity than existing large wind or solar plants currently in NorthWestern's queue for interconnection requests.

Navigant is not aware of any study that quantified T&D reliability improvements due to NEM solar.[28] For this reason and the other reasons stated above, avoided outage costs are assumed to be zero for the duration of the study.

If reduced outage costs can be identified and quantified in the future, Navigant recommends applying value of service (VOS) to reduced outage duration projections to quantify the economic value of reduced outage duration. The VOS could apply to individual owners if they were to configure their system(s) such that they could operate in a standalone mode (i.e., as a microgrid) and would receive reliability benefits. However, because the study focuses on electric utility costs and benefits, Navigant did not include the value of solar PV on customer reliability for systems capable of operating in a standalone mode, for either the UCT or RIM tests.

### *2.5.11 Non-Energy Benefits*

Non-energy benefits typically include categories such as increased customer satisfaction, fewer service complaints, decreased land use, reduced water consumption, etc. Navigant considers these non-energy benefits to be subjective, not quantifiable, and not measurable at this time. Furthermore, the team's research indicates the non-energy benefits typically are not monetized in other value of solar studies (e.g., Lawrence Berkeley National Laboratory Study in California, Clean Power Research Study in Minnesota, South Carolina Office of Regulatory Staff).

### *2.5.12 Other Benefits*

Navigant considered other potential benefits of solar such as equipment life extension, increased jobs, increased real estate value, and backup generation when paired with battery storage. However, Navigant considers the quantification of these benefits to be subjective, not quantifiable, and not measurable at this time.

## 2.6 Cost Calculation Methodologies

### *2.6.1 Reduced Revenue*

Navigant derived the loss of revenue (sales) for NEM customers with solar PV for each of the solar forecast scenarios. The team applied current rates for each of NorthWestern's bill categories (i.e., supply energy, supply deferred costs, distribution energy, CTC-QF, USBC, transmission demand, and distribution demand) as applicable to customers with solar PV up to 50 kW, split by customer class (i.e., residential, general secondary demand, general secondary non-demand, general primary demand, and general primary non-demand). To forecast future rates, Navigant applied retail rate annual growth factors

[28] Navigant is familiar with the significant amount of literature and theoretical analysis that has been published on the potential for solar to provide reliability benefits to T&D facilities, particularly those assessing the impact of combined energy storage and solar. However, to the best of Navigant's knowledge, none of these studies are able to quantify reliability benefits associated with specific T&D lines or substations. Benefits associated with firm solar capacity are captured in the avoided generation and T&D capacity sections of the report.

based on a US Energy Information Administration forecast.[29] This is a similar methodology as used in NREL's study.

For each customer class, the Navigant team used an average customer size based on NorthWestern's customer data, assumed an average solar system size, determined the number of PV systems corresponding to each adoption forecast, estimated the reduction in energy consumption and peak demand due to the presence of solar, and multiplied these impacts by the respective bill components to estimate reduced revenue. For the energy component of the reduced revenue calculation, Navigant assumed that customers properly size their PV systems so that all excess energy carryover from month-to-month is consumed by the customer in each year. Thus, the entire energy production of the PV systems is included in the calculation.

Table 10 summarizes the 25-year levelized reduced revenue value by solar adoption forecast.

**Table 10. Levelized Reduced Revenue (25-Year)**

| Solar NEM Scenario | Total Cost: 25-Year Levelized ($/kWh) |
|---|---|
| Low Forecast | -$0.146 |
| Medium Forecast | -$0.144 |
| High Forecast | -$0.144 |

*Source: Navigant*

### *2.6.2 Administrative Costs*

Navigant developed administrative costs based on an analysis of application fees performed by NorthWestern. Navigant reviewed NorthWestern's approach and assumptions, and believes it provides a reasonable estimate of the additional administrative costs NorthWestern will incur for each new NEM system included in the solar forecast.[30] The fee's details are in Table 11.

[29] US Energy Information Administration, *Annual Energy Outlook 2017*, https://www.eia.gov/outlooks/aeo/data/browser/#/?id=62-AEO2017&region=3-21&cases=ref_no_cpp~highmacro~lowmacro&start=2015&end=2050&f=A&linechart=~~~ref_no_cpp-d120816a.108-62-AEO2017.3-21~highmacro-d120816a.108-62-AEO2017.3-21~lowmacro-d120816a.108-62-AEO2017.3-21&map=&chartindexed=1&sourcekey=0.

[30] In the later years of the study when solar capacity is high (e.g., greater than 200 MW), NorthWestern likely will incur additional costs for energy management and control systems that will be needed to enable system control room operators to visualize solar NEM impacts on a real-time basis, and provide operators with the ability to control solar output during emergencies or for routine maintenance. These systems include distributed energy resource management systems (DERMS) and advanced distribution management systems (ADMS). Navigant has not included costs for new control systems and technology.

**Table 11. NEM Application Fee Derivation**

| Task | Description | Division | Labor Category | Rate | Time (hours) | Cost |
|---|---|---|---|---|---|---|
| Application Screen | Review application for certification conformity and completeness | RA-Regulatory Support Services | Senior Engineer | $58.09 | 0.25 | $14.52 |
| Application Screen | Review feeder location for net meter | DO-Electric Assets | Senior Engineer | $58.09 | 0.50 | $29.05 |
| Agreement Development | Develop Agreement | TR-Regional Planning | Coordinator | $58.09 | 2.00 | $116.18 |
| Net Meter Database Update | Update Net Meter Database | RA-Regulatory Affairs | Rate Analyst | $64.85 | 0.25 | $16.21 |
| Geographic Information System (GIS) Update | Update GIS with distributed generation (DG) system information | DO-Drafting and Mapping | Drafter | $25.00 | 0.50 | $12.50 |
| Service Order Development | Create/Close Service Order | CC-Distribution Dispatch | Dispatcher | $20.95 | 0.25 | $5.24 |
| | | | | | **Total** | **$193.70** |

*Source: NorthWestern Energy*

Navigant recommends that NorthWestern revisit its estimation of administrative costs in future years in order to consider any additional costs of NEM on full time equivalent labor and future implementation of a distribution energy resource management system (DERMS), advanced distribution management systems (ADMS), system controls, etc.

Table 12 summarizes the 25-year levelized administrative costs value by solar adoption forecast.

**Table 12. Levelized Administrative Costs (25-Year)**

| Solar NEM Scenario | Total Cost: 25-Year Levelized ($/kWh) |
|---|---|
| Low Forecast | -$0.003 |
| Medium Forecast | -$0.003 |
| High Forecast | -$0.003 |

*Source: Navigant*

### *2.6.3 Interconnection Costs*

Typically, utilities accrue interconnection costs for NEM solar when a large amount of solar is installed in areas where load density is high, such as when several NEM customers are connected to a single transformer or when lines are operating at secondary voltages. Interconnection costs also may arise when an NEM customer installs solar whose capacity exceeds the rating of the transformer or service line. Because NEM solar owners are able to carry over excess energy transfers for 1 year according to NorthWestern's current NEM tariff rule, most customers will avoid oversizing solar with attendant noncompensation for unrecoverable energy accrued after the 1-year carryover period has expired.

Accordingly, Navigant estimates interconnection costs at zero for all scenarios.

### *2.6.4 Integration Costs*

In addition to interconnection costs, Navigant evaluated the cost to connect NEM solar to the grid that otherwise is not recoverable from customers owning NEM solar PV. For example, costs that may be incurred to connect solar PV include upgrades to mitigate primary and secondary line and transformer overloads, impacts on protection coordination and settings, and other site-specific distribution upgrades. Similarly, variable solar output can create large swings in feeder voltage with resulting power quality impacts and compromising of protective relay coordination. Large quantities of solar also can impact the higher voltage transmission system, particularly when solar output flows into the transmission system. Similar to impacts on distribution facilities, high solar PV capacity could result in integration costs due to the need to mitigate the variable solar output that it may have on voltage performance, protection requirements, and thermal overloads.

Navigant excluded these potential costs as the amount of installed solar capacity per feeder (substation) was limited to an amount that would prevent reserve power flow on distribution feeders. Because these limits were incorporated into the solar forecast, Navigant assumed any mitigation that may be required on NorthWestern's T&D system would be small and therefore can be excluded. Accordingly, Navigant estimates integration costs at zero for all scenarios.

### *2.6.5 Other Costs*

Navigant understands that costs associated with other categories—such as ancillary services, security risk, and environmental issues—could occur due to the presence of NEM. The Navigant team considered the monetization of these costs to be subjective, not quantifiable, and not measurable at this time and therefore did not assign any value to these cost categories in this study.

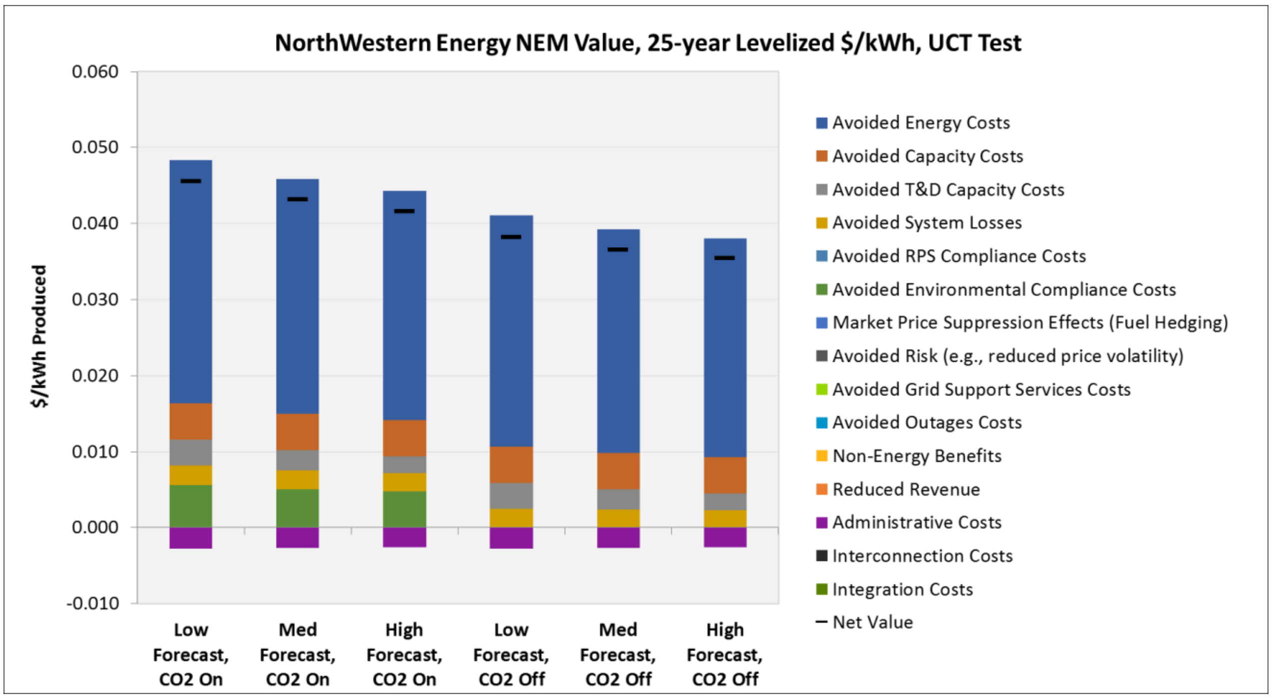
# 3. RESULTS

This section presents the 25-year levelized and annual net avoided costs of the study.

## 3.1 Levelized Net Avoided Costs

Figure 3 shows the levelized net avoided costs over a 25-year analysis period (2018-2042) from the UCT perspective for the three adoption forecasts and two $CO_2$ price scenarios. Each stacked bar includes the costs and benefits specific to that scenario. The dash mark on each stacked bar indicates the net value (i.e., the sum of benefits minus the sum of costs).

**Figure 3. Graphical Levelized Net Avoided Costs for the UCT Test**




*Source: Navigant analysis*

Table 13 shows the same UCT test results in tabular form as shown in Figure 3.

**Table 13. Tabular Levelized Net Avoided Costs in $/kWh Based on UCT Test**

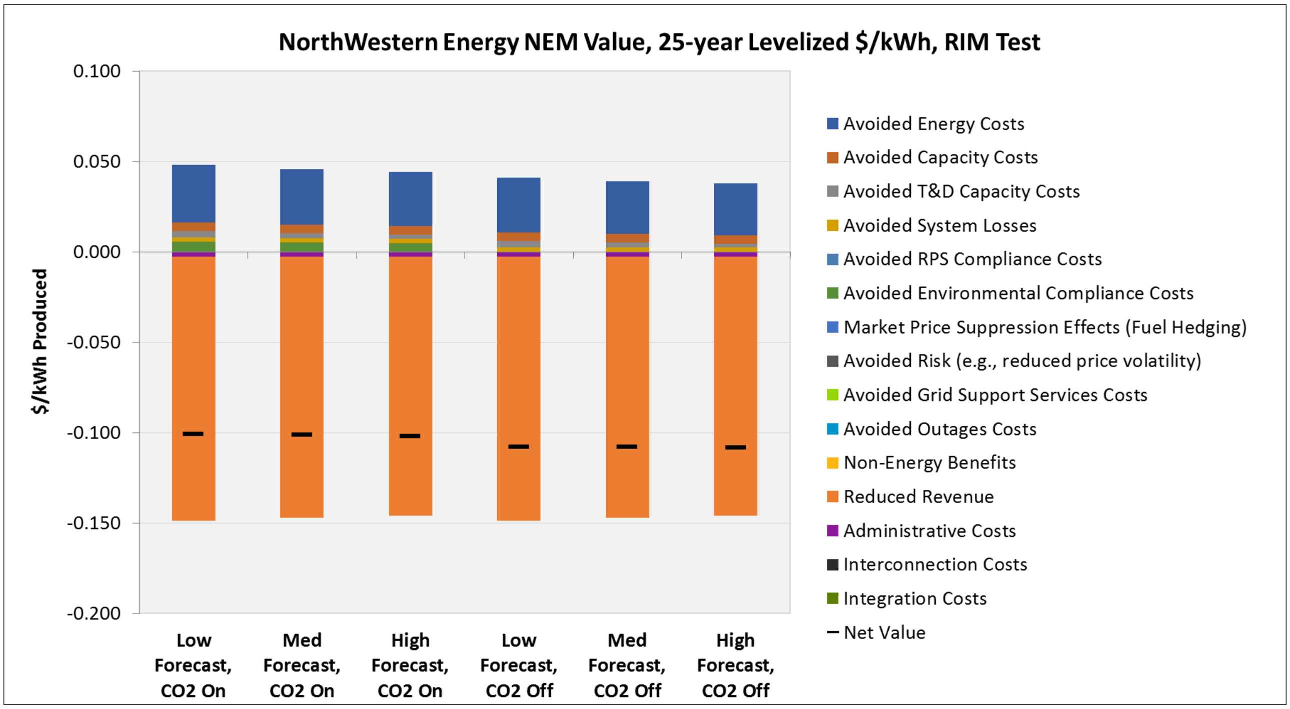
| Value Stream | Adoption Forecast: / $CO_2$ Price Scenario: | Low On | Med On | High On | Low Off | Med Off | High Off |
|---|---|---|---|---|---|---|---|
| Avoided Energy Costs | | $0.032 | $0.031 | $0.030 | $0.030 | $0.029 | $0.029 |
| Avoided Capacity Costs | | $0.005 | $0.005 | $0.005 | $0.005 | $0.005 | $0.005 |
| Avoided T&D Capacity Costs | | $0.003 | $0.003 | $0.002 | $0.003 | $0.003 | $0.002 |
| Avoided System Losses | | $0.003 | $0.002 | $0.002 | $0.002 | $0.002 | $0.002 |
| Avoided RPS Compliance Costs | | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 |
| Avoided Environmental Compliance Costs | | $0.006 | $0.005 | $0.005 | $0.000 | $0.000 | $0.000 |
| Market Price Suppression Effects | | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 |
| Avoided Risk | | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 |
| Avoided Grid Support Services Costs | | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 |
| Avoided Outages Costs | | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 |
| Non-Energy Benefits | | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 |
| Reduced Revenue | | N/A | N/A | N/A | N/A | N/A | N/A |
| Administrative Costs | | -$0.003 | -$0.003 | -$0.003 | -$0.003 | -$0.003 | -$0.003 |
| Interconnection Costs | | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 |
| Integration Costs | | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 |
| **Net Value** | | $**0.046** | $**0.043** | $**0.042** | $**0.038** | $**0.037** | $**0.035** |

*Source: Navigant analysis*

The net value of solar generally decreases as the adoption levels increase. This trend is driven primarily by the avoided energy costs and the avoided T&D capacity costs. For avoided energy costs, these trends are based on the PowerSimm production cost modeling outputs. For avoided T&D capacity costs, Navigant found a non-linear trend between the solar adoption forecasts and the deferrable distribution system capacity investments which caused differences in the levelized avoided T&D capacity costs benefit stream. It also important to note that reduced revenue is considered a transfer in the UCT, so these values show up as “N/A” in the results shown in Table 13.

Figure 4 shows the levelized results over a 25-year analysis period from the RIM test perspective for the three adoption forecasts and two $CO_2$ price scenarios. In the RIM test, reduced revenue is considered a cost versus the UCT where it is considered a transfer. The dash mark on each stacked bar indicates the net value (i.e., the sum of benefits minus the sum of costs).

**Figure 4. Graphical Levelized Net Avoided Costs Based on RIM Test**




*Source: Navigant analysis*

Table 14 shows the same results in tabular form as shown in Figure 4.

**Table 14. Tabular Levelized Net Avoided Costs in $/kWh Based on RIM Test**

| Value Stream | Adoption Forecast: $CO_2$ Price Scenario: | Low On | Med On | High On | Low Off | Med Off | High Off |
|---|---|---|---|---|---|---|---|
| Avoided Energy Costs | | $0.032 | $0.031 | $0.030 | $0.030 | $0.029 | $0.029 |
| Avoided Capacity Costs | | $0.005 | $0.005 | $0.005 | $0.005 | $0.005 | $0.005 |
| Avoided T&D Capacity Costs | | $0.003 | $0.003 | $0.002 | $0.003 | $0.003 | $0.002 |
| Avoided System Losses | | $0.003 | $0.002 | $0.002 | $0.002 | $0.002 | $0.002 |
| Avoided RPS Compliance Costs | | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 |
| Avoided Environmental Compliance Costs | | $0.006 | $0.005 | $0.005 | $0.000 | $0.000 | $0.000 |
| Market Price Suppression Effects | | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 |
| Avoided Risk | | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 |
| Avoided Grid Support Services Costs | | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 |
| Avoided Outages Costs | | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 |
| Non-Energy Benefits | | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 |
| Reduced Revenue | | -$0.146 | -$0.144 | -$0.144 | -$0.146 | -$0.144 | -$0.144 |
| Administrative Costs | | -$0.003 | -$0.003 | -$0.003 | -$0.003 | -$0.003 | -$0.003 |
| Interconnection Costs | | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 |
| Integration Costs | | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 |
| **Net Value** | | **-$0.101** | **-$0.101** | **-$0.102** | **-$0.108** | **-$0.108** | **-$0.108** |

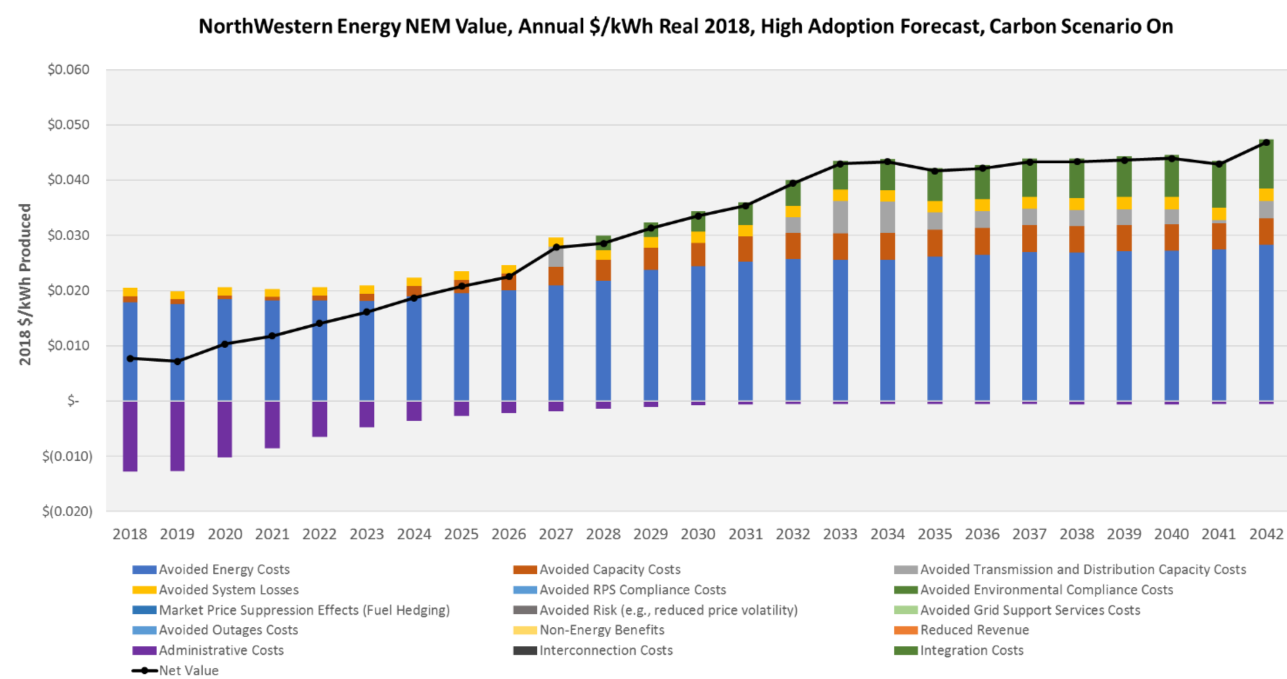
*Source: Navigant analysis*

From the RIM test perspective, the net value of solar is negative for all adoption forecasts and $CO_2$ price scenarios due to the inclusion of reduced revenue as a cost.

## 3.2 Annual Net Avoided Costs

Figure 5 shows annual benefit and cost streams from the UCT perspective in real 2018 dollars per kilowatt-hour produced by the solar PV systems under the high adoption scenario with carbon pricing included. The black line represents the net value (sum of benefits minus sum of costs) in each year.

**Figure 5. Annual Net Avoided Costs Based on UCT Test, High Forecast, Carbon On**




*Source: Navigant analysis*

Overall, the value of solar in real dollars tends to increase over time. The avoided T&D costs do not follow a smooth year-over-year trend because Navigant tied the analysis to specific investment costs that would be incurred and potentially deferred in each year due to the presence of solar. Avoided environmental compliance costs are observed starting in 2028 based on the pricing forecast described in Appendix A. Administrative costs are front-loaded on a per-kilowatt-hour basis because the team assumed a one-time administrative fee when each PV system is installed. Therefore, in the later years once the market reaches saturation, there are minimal new systems being installed each year, and the majority of systems are already in place and producing benefits to the grid.

Annual results for each solar forecast, carbon price scenario, and cost test are found in Appendix C.

## 3.3 Recommendations for Future Studies

Navigant recommends that NorthWestern consider the following future studies and analysis to further refine the avoided costs and benefits that Navigant developed and reported in this study. The team's recommendations are based on findings from its analysis of each of the benefit and cost categories in the report.

1. Update the solar adoption forecasts to include an NEM rate adjustment to account for the difference in annual NEM rate versus net avoided cost of solar energy production
2. Conduct an ELCC study using probabilistic methods such as loss-of-load expectation or other industry-accepted approaches to predict the amount of firm capacity attributable to NEM solar
3. Conduct distribution feeder hosting capacity studies once a significant level of solar NEM is adopted on the system in order to determine the maximum amount of solar capacity that can be installed on each feeder without mitigation or system upgrades
4. Update transmission loss factors via load flow simulations of the current network configuration and current resource mix within NorthWestern's BA
5. Identify the additional systems and processes that will be required when installed NEM solar capacity reaches a pre-determined threshold; these systems include DERMS, ADMS, updates to the billing system and customer information system, and other new IT and OT
6. Update wholesale tariff allocation factors for solar once sufficient data is available from solar installations within NorthWestern's service territory

# APPENDIX A. $CO_2$ PRICE FORECAST

## A.1 Methodology

The $CO_2$ price forecast is based on Navigant's *Mid-Year 2017 Energy Market Outlook*, finalized in July of 2017. Navigant's market modeling approach relies on a multifaceted approach for modeling and simulating the energy market and studying the performance of energy assets in the marketplace. Navigant's approach relies on the involvement of numerous subject matter experts with specific knowledge and understanding of several fundamental assumptions, such as fuel pricing, generation development, transmission infrastructure expansion, asset operation, environmental regulations, and technology deployment. From its involvement in the industry, Navigant has specific and independent views on many of these fundamental assumptions based on its knowledge and understanding of the issues. Provided below is an overview of the modeling process.

Navigant's proprietary Portfolio Optimization Model (POM) is a linear optimization model used for capacity expansion. POM simulates economic investment decisions and power plant dispatch on a zonal basis subject to capital costs, reserve margin planning requirements, RPS, fuel costs, fixed and variable O&M costs, emissions allowance costs, and zonal transmission interface limits. This model incorporates the same generation base, demand forecasts, fuel prices, other operating costs, and plant parameters that are utilized throughout the market simulation modeling process. The model simultaneously performs least-cost optimization of the electric power system expansion and dispatch in multi-decade time horizons. POM can perform multivariate optimization, which can consider value propositions other than cost minimization, such as sustainability, technological innovation, or impacts on other sectors, such as natural gas. POM was used to determine the $CO_2$ prices that would result from a likely $CO_2$ emission reduction policy.

Navigant also uses the Gas Pipeline Competition Model (GPCM) to develop our Reference Case Gas Price Forecast. GPCM is a commercial linear-programming model of the North American gas marketplace and infrastructure. Navigant applies its own analysis to provide macroeconomic outlook and natural gas supply and demand data for the model, including infrastructure additions and configurations, and its own supply and demand elasticity assumptions. Forecasts are based upon the breadth of Navigant's view, insight, and detailed knowledge of US and Canadian natural gas markets. Adjustments are made to the model to reflect accurate infrastructure operating capability and the rapidly changing market environment regarding economic growth rates, energy prices, gas production growth levels, demand by sector and natural gas pipeline, storage, and liquified natural gas terminal system additions and expansions. To capture current expectations for the gas market, this long-term monthly forecast is combined with near-term New York Mercantile Exchange average forward prices for the first 2 years of the forecast.

## A.2 Assumptions

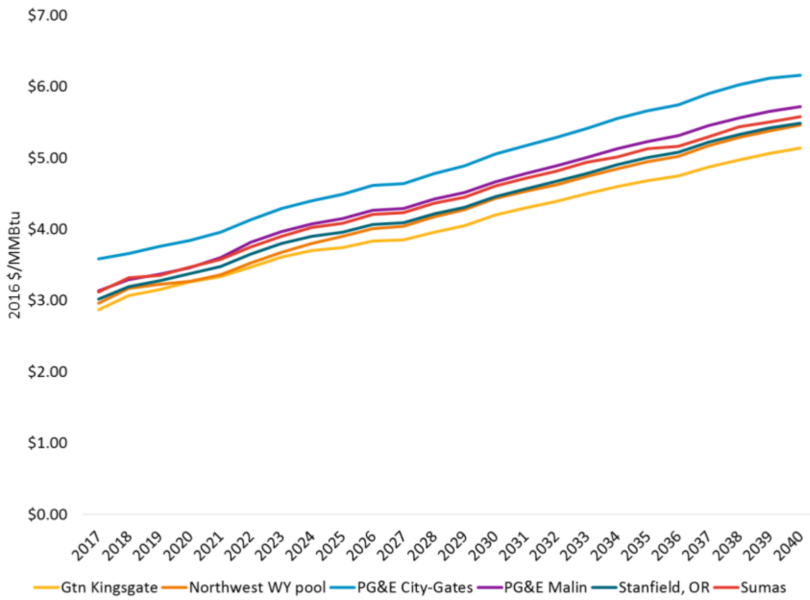
Two major assumptions tied to $CO_2$ emissions are natural gas prices and capacity additions and retirements. Both assumptions discussed in this section relate to the entire Northwest Power Pool[31] (NWPP) subregion of WECC, in which the majority of Montana is located. The gas price and capacity changes are taken from Navigant's *Mid-Year 2017 Energy Market Outlook*.

[31] The Northwest Power Pool does not include the Basin subregion.

**Natural Gas Prices**

Forecasted natural gas prices for major gas hubs in NWPP are shown in Figure 6. Gas prices were approximately $3.00/MMBtu in 2017 and reach prices between $5.00/MMBtu and $6.00/MMBtu by 2040. Historically, the Pacific Gas and Electric City-gate price has been one of the highest and most traded in the region; this trend is expected to continue through the forecast with significantly higher prices than the other gas hubs in the region. All prices are in real 2016 dollars.

**Figure 6. NWPP Natural Gas Prices**

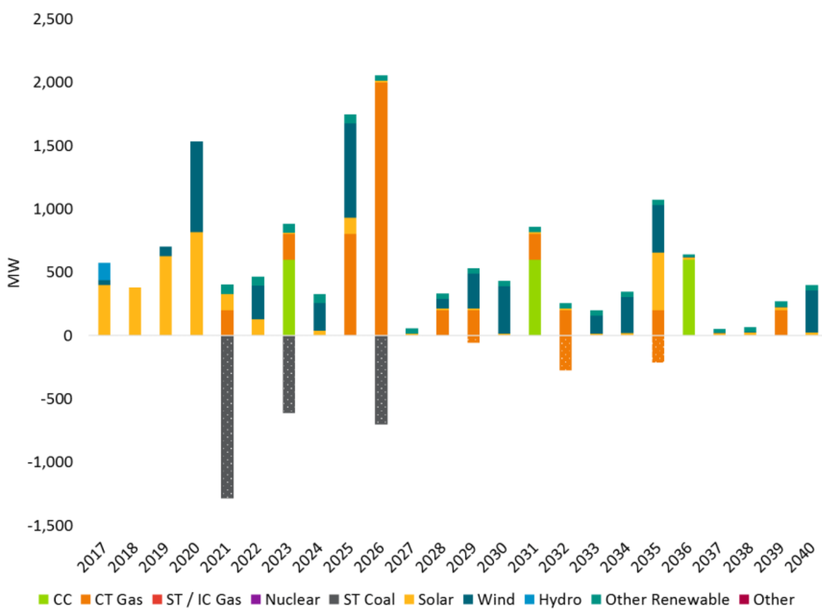



*Source: Navigant Mid-Year 2017 Forecast*

**Additions and Retirements**

Capacity additions and retirements of all types for the NWPP are shown in Figure 7. Resource additions in the region consist of some near- and mid-term natural gas combined-cycle capacity, substantial renewable resource additions, and assumed generic simple-cycle capacity needed to maintain generation reserves. There are significant coal retirements included in the first half of the forecast, driven primarily by the US Environmental Protection Agency's regional haze determinations; these coal retirements lead to significant reduction in $CO_2$ emissions.

**Figure 7. Capacity Additions and Retirements**




*Source: Navigant Mid-Year 2017 Forecast*

**$CO_2$ Policy**

Navigant assumed a cap-and-trade policy that targets 28% reductions of $CO_2$ emissions from the power generation sector from 2005 levels in 2028, ramping up 1% each year to 50% in 2050. As a comparison, under the Paris Agreement, the US agreed to reduce overall emissions (i.e., not just the power sector) by 26%-28% from 2005 levels by 2025. This cap-and-trade program would apply to the entire WECC region, except for California, whose current program targets getting to 1990 emission levels overall by 2020 and 80% below 1990 levels by 2050.

**Extrapolation for 2041 through 2050**

POM is currently set up to run through 2040, so Navigant extrapolated the $CO_2$ price results from POM from 2041 through 2050. There is a direct relationship between the annual emissions to generation ratio (total $CO_2$ emissions in tons divided by total generation in kilowatt-hours) and the $CO_2$ price. Navigant linearly extrapolated the emissions to generation ratio for 2041 through 2050, based on the results from POM.

Navigant then used the relationship between the emissions to generation ratio and the $CO_2$ price to calculate the $CO_2$ price for 2041 through 2050.

## A.3 Results

Table 15 shows forecast annual $CO_2$ prices through 2050; prices are shown in real 2016 dollars per short ton and nominal dollars per short ton. [32]

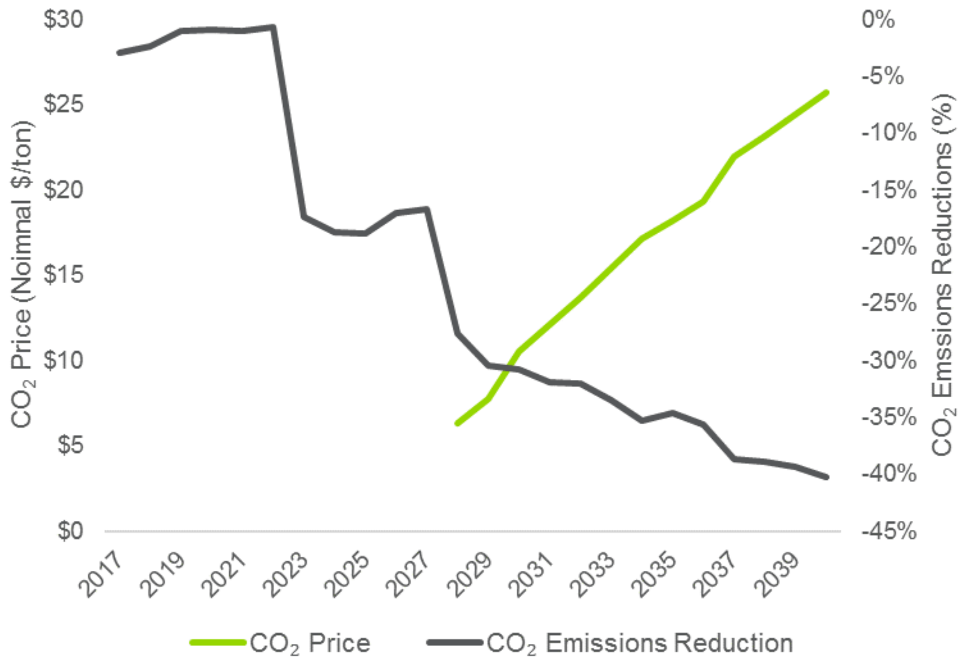
**Table 15. Annual WECC $CO_2$ Price**

| | $CO_2$ Price (2016 $/ton) | $CO_2$ Price (Nominal $/ton) |
|---|---|---|
| **2017** | - | - |
| **2018** | - | - |
| **2019** | - | - |
| **2020** | - | - |
| **2021** | - | - |
| **2022** | - | - |
| **2023** | - | - |
| **2024** | - | - |
| **2025** | - | - |
| **2026** | - | - |
| **2027** | - | - |
| **2028** | $5.00 | $6.34 |
| **2029** | $6.00 | $7.76 |
| **2030** | $8.00 | $10.56 |
| **2031** | $9.00 | $12.11 |
| **2032** | $10.00 | $13.73 |
| **2033** | $11.00 | $15.40 |
| **2034** | $12.00 | $17.14 |
| **2035** | $12.50 | $18.21 |
| **2036** | $13.00 | $19.32 |
| **2037** | $14.50 | $21.98 |
| **2038** | $15.00 | $23.19 |
| **2039** | $15.50 | $24.44 |
| **2040** | $16.00 | $25.73 |
| **2041** | $17.63 | $28.92 |
| **2042** | $18.52 | $30.99 |
| **2043** | $19.41 | $33.13 |
| **2044** | $20.30 | $35.35 |
| **2045** | $21.19 | $37.64 |
| **2046** | $22.09 | $40.01 |
| **2047** | $22.98 | $42.46 |
| **2048** | $23.87 | $44.99 |
| **2049** | $24.76 | $47.60 |
| **2050** | $25.66 | $50.30 |

[32] Nominal prices determined using a 2% annual inflation rate based on a 20-year average inflation escalation for GDP, provided by the US Bureau of Economic Analysis.

Figure 8 shows the relationship between the carbon price and reduction in emissions relative to the 2005 level. The sharp drop in emissions reduction that occur prior to the implementation of the carbon price correspond to years in which significant amounts of coal capacity retire. The relationship between carbon price and emissions reduction is also evident in Figure 8.

**Figure 8 . $CO_2$ Price and $CO_2$ Emissions**



# APPENDIX B. LEVELIZATION DERIVATION

This section describes the methodology that Navigant applied to calculate levelized values in this study.

The net present value of net value is calculated as follows:

$$NPV\ of\ Net\ Value = \sum_{y=1}^{Y} \frac{P_y E_y}{(1+d)^{y-1}}$$

Where:

Y = number of years
y = year
P = price
E = energy production from solar NEM
d = discount factor (i.e., WACC)

Navigant defines a levelized price as that single price which, when multiplied by energy production from solar NEM in each year, equals the NPV of the net value of solar NEM.

$$\sum_{y=1}^{Y} \frac{P_{LEV} E_y}{(1+d)^{y-1}} = NPV\ of\ Net\ Value$$

The levelized priced can be moved outside the summation, since it does not have a year subscript. Rearranging terms shows that the levelized price equals the NPV of net value divided by the discounted stream of energy production.

$$P_{LEV} = \frac{NPV\ of\ Net\ Value}{\sum_{y=1}^{Y} \frac{E_y}{(1+d)^{y-1}}}$$

# APPENDIX C. DETAILED ANNUAL NET AVOIDED COSTS

**Figure 9. Annual Net Value in Real $/kWh Based on UCT Test, Low Adoption, Carbon Off**

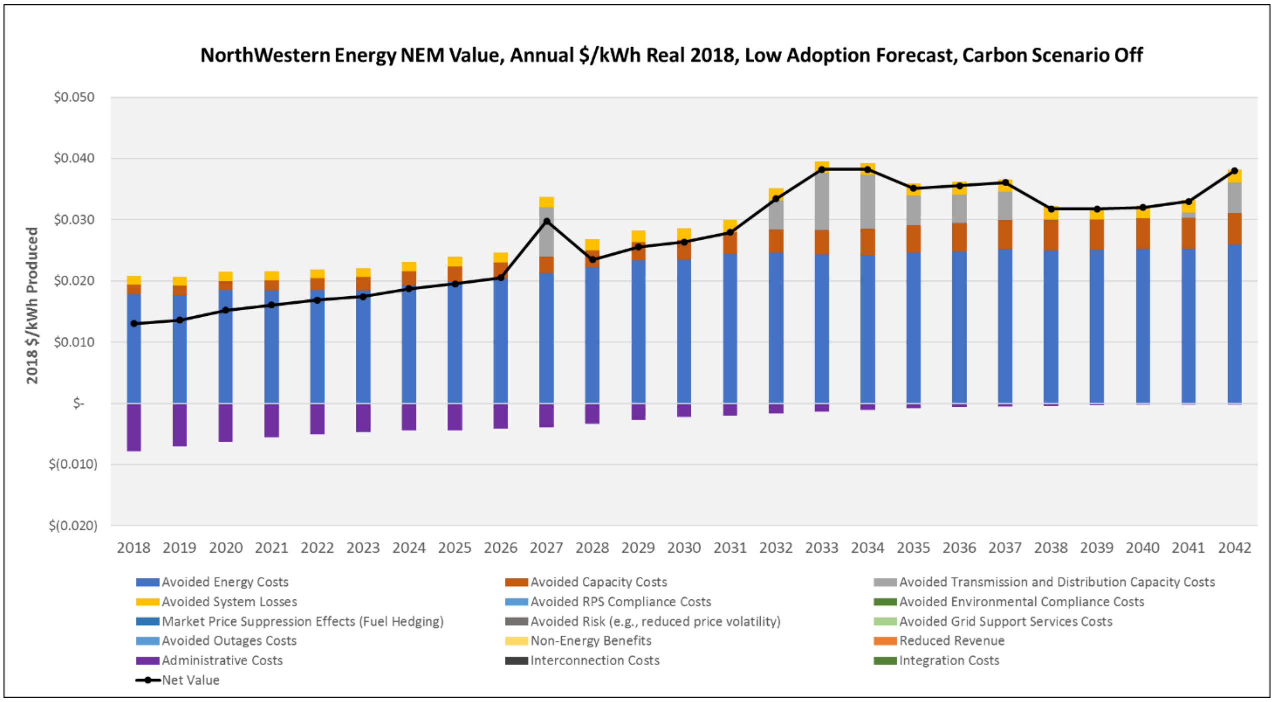



**Figure 10. Annual Net Value in Real $/kWh Based on RIM Test, Low Adoption, Carbon Off**

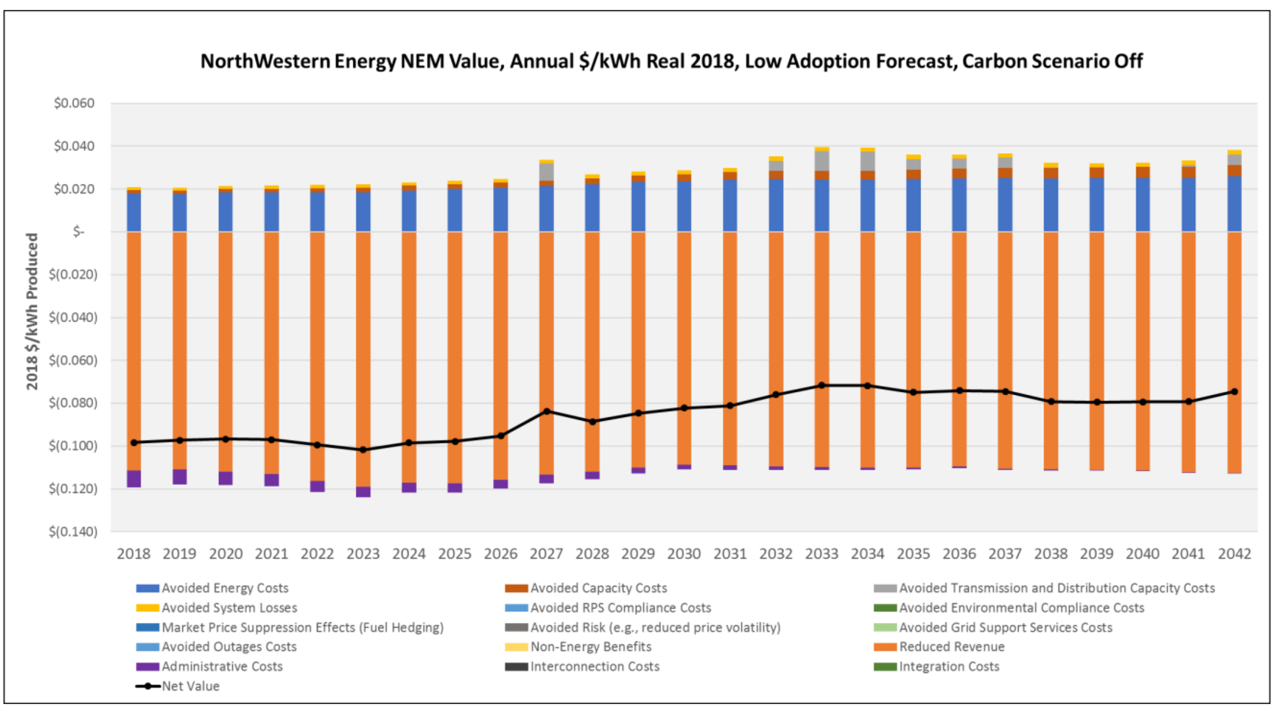


**Figure 11. Annual Net Value in Real $/kWh Based on UCT Test, Medium Adoption, Carbon Off**

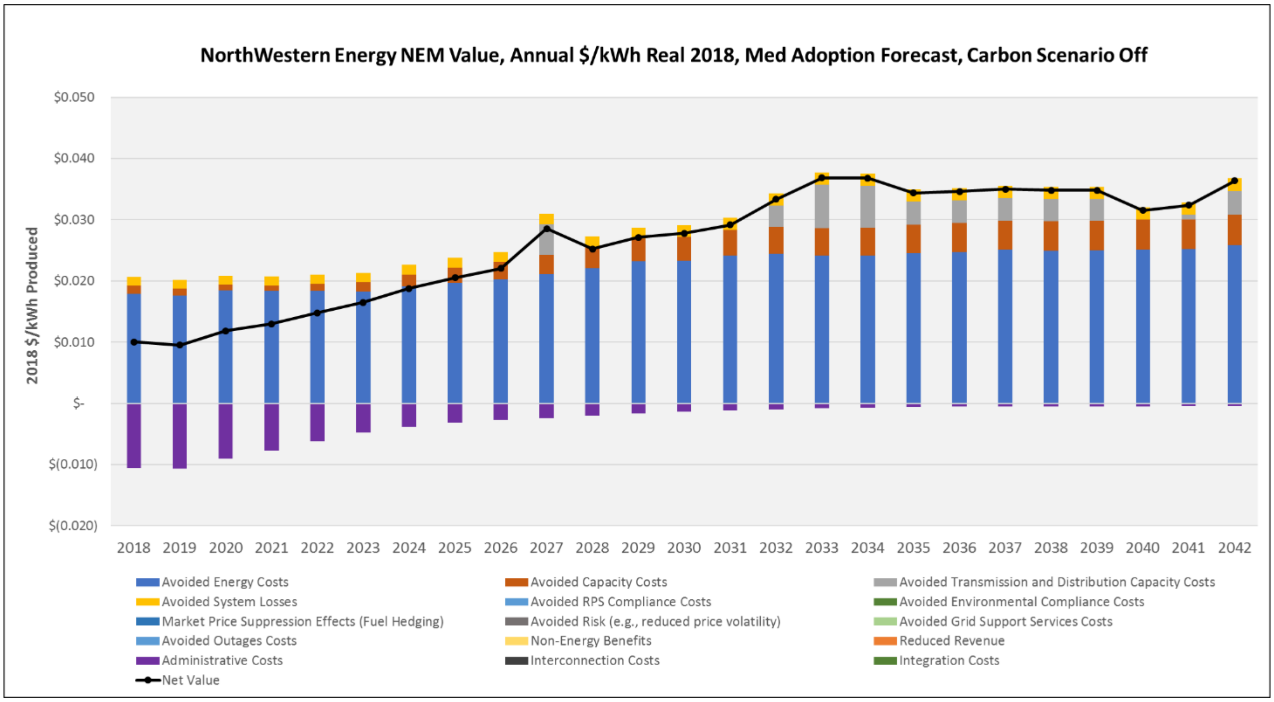



**Figure 12. Annual Net Value in Real $/kWh Based on RIM Test, Medium Adoption, Carbon Off**

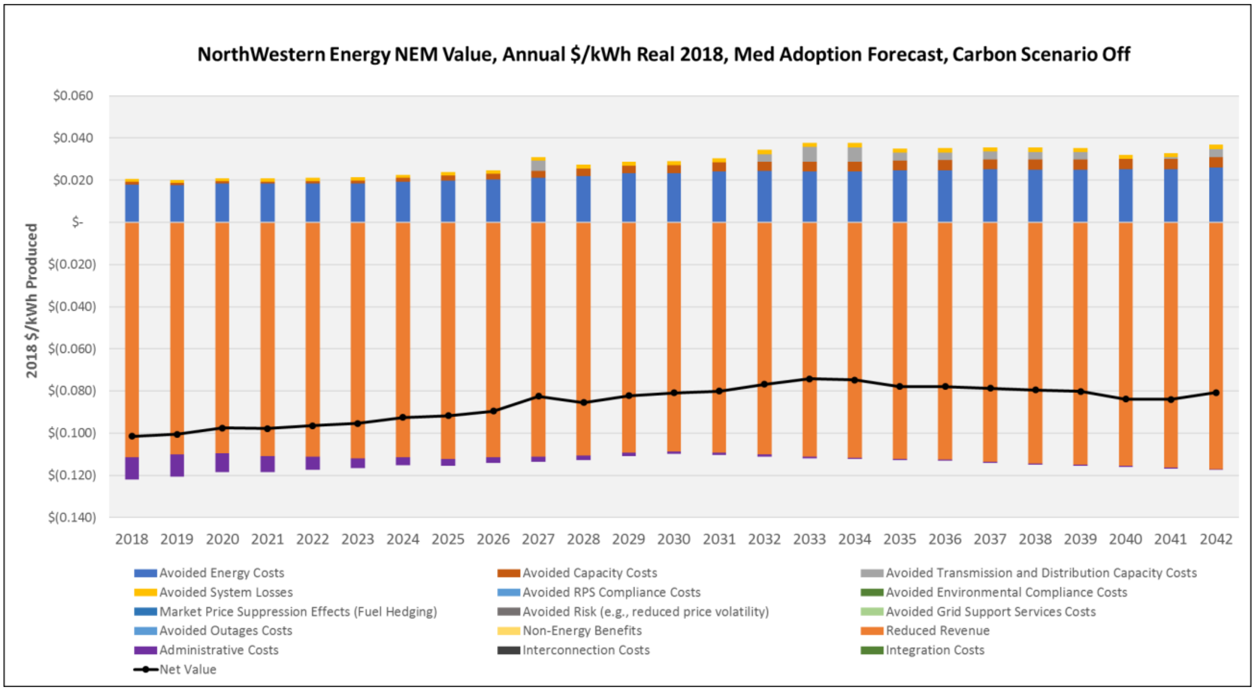


**Figure 13. Annual Net Value in Real $/kWh Based on UCT Test, High Adoption, Carbon Off**

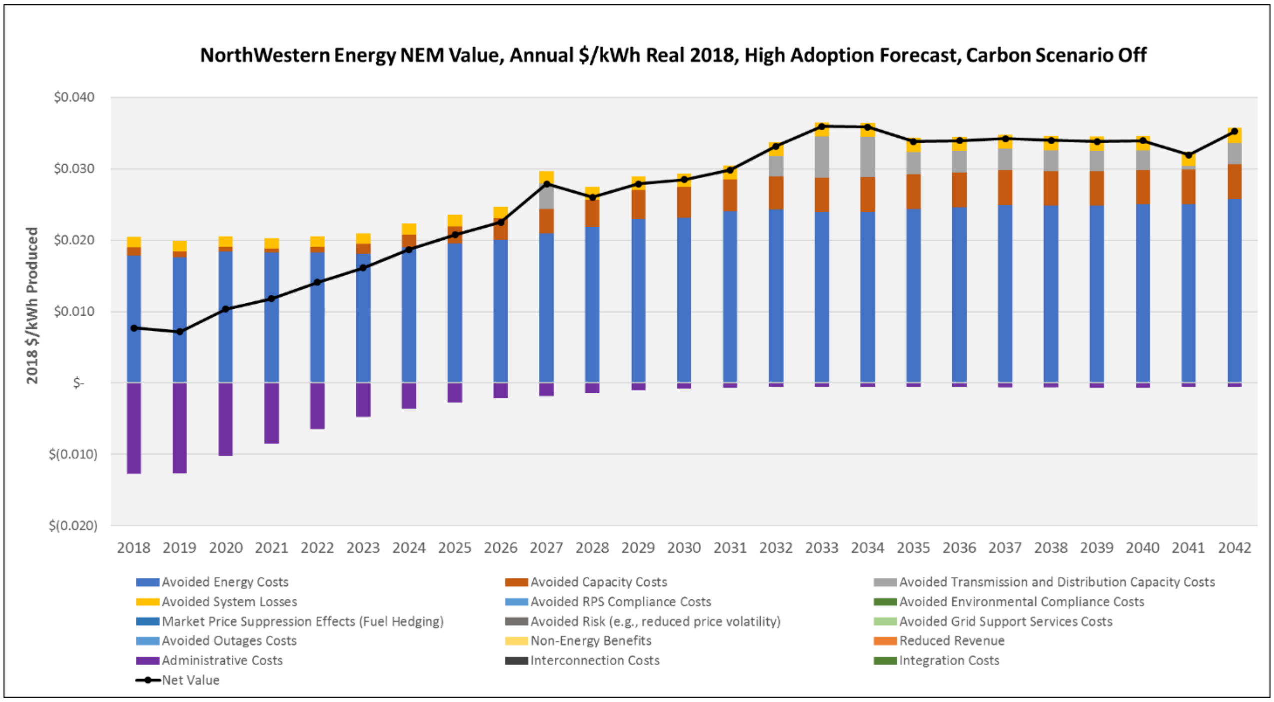



**Figure 14. Annual Net Value in Real $/kWh Based on RIM Test, High Adoption, Carbon Off**

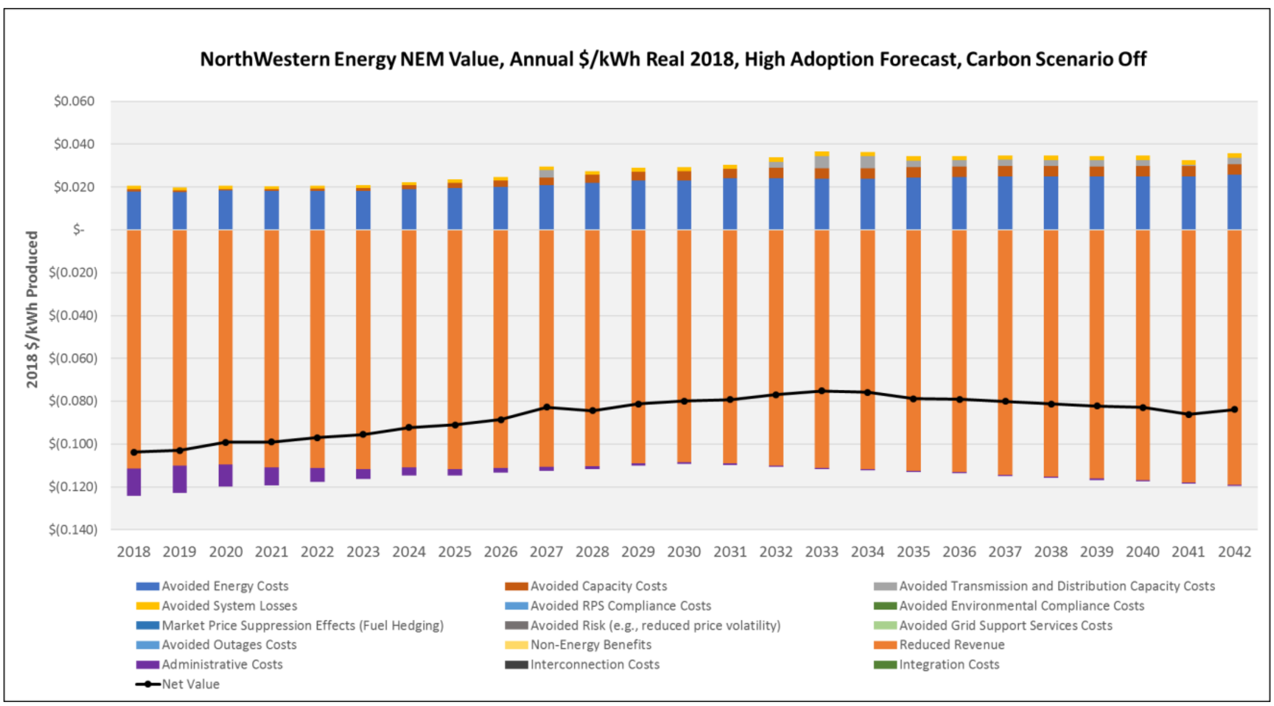


**Figure 15. Annual Net Value in Real $/kWh Based on UCT Test, Low Adoption, Carbon On**

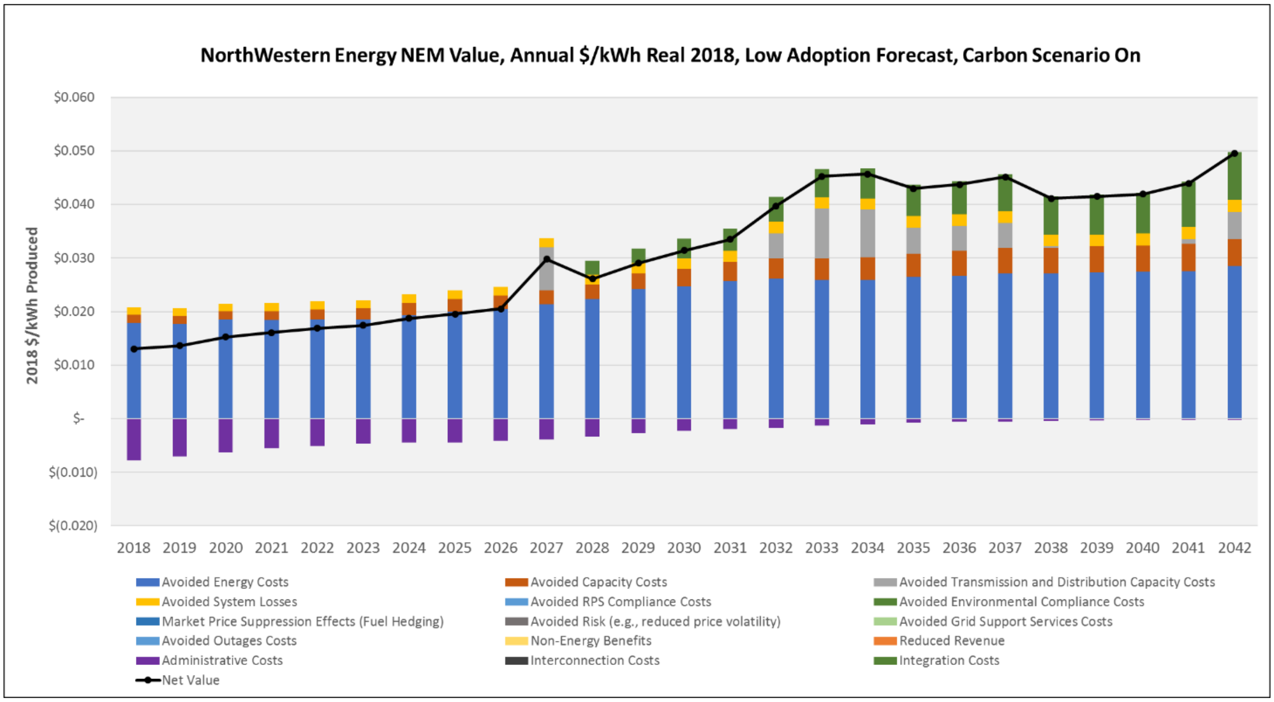



**Figure 16. Annual Net Value in Real $/kWh Based on RIM Test, Low Adoption, Carbon On**

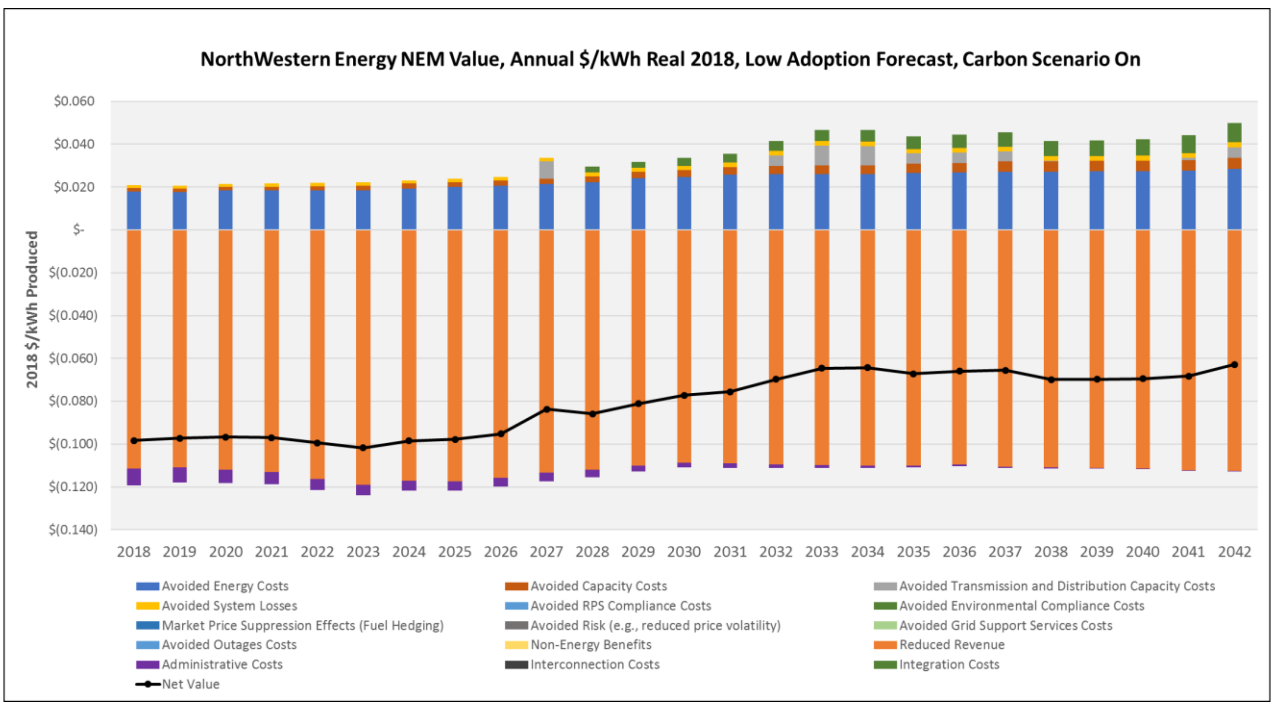


**Figure 17. Annual Net Value in Real $/kWh Based on UCT Test, Medium Adoption, Carbon On**

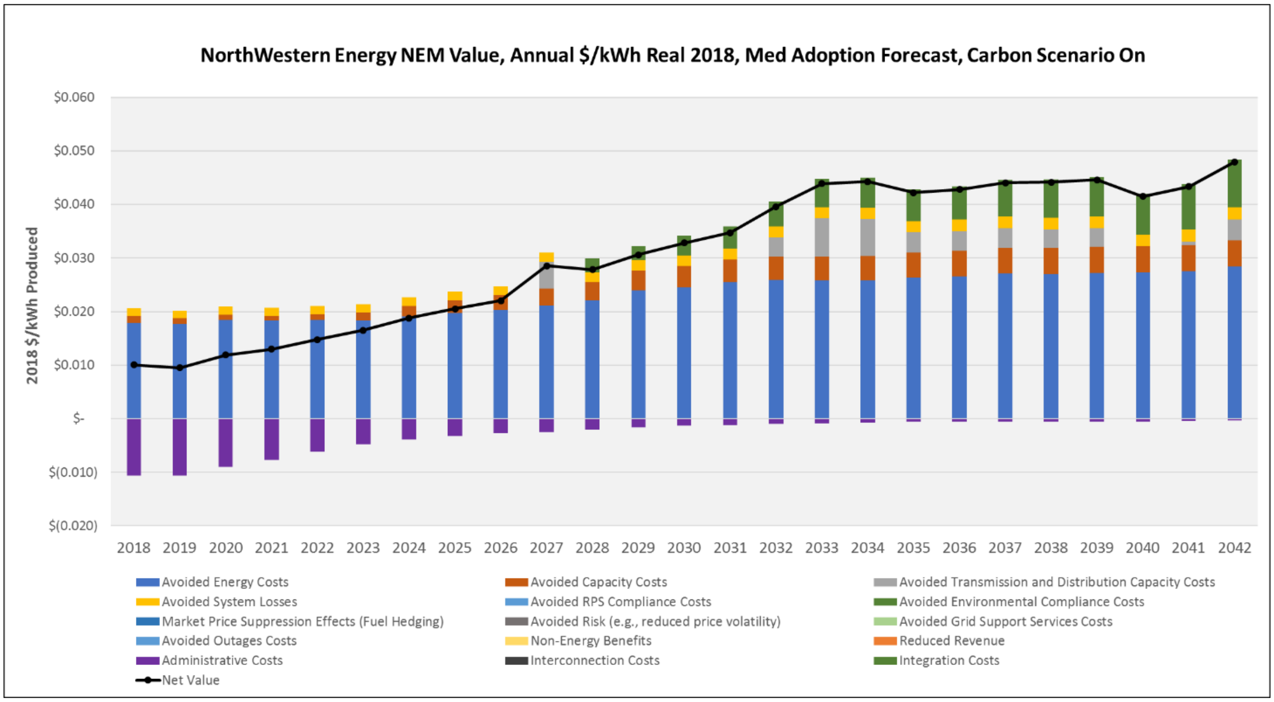



**Figure 18. Annual Net Value in Real $/kWh Based on RIM Test, Medium Adoption, Carbon On**

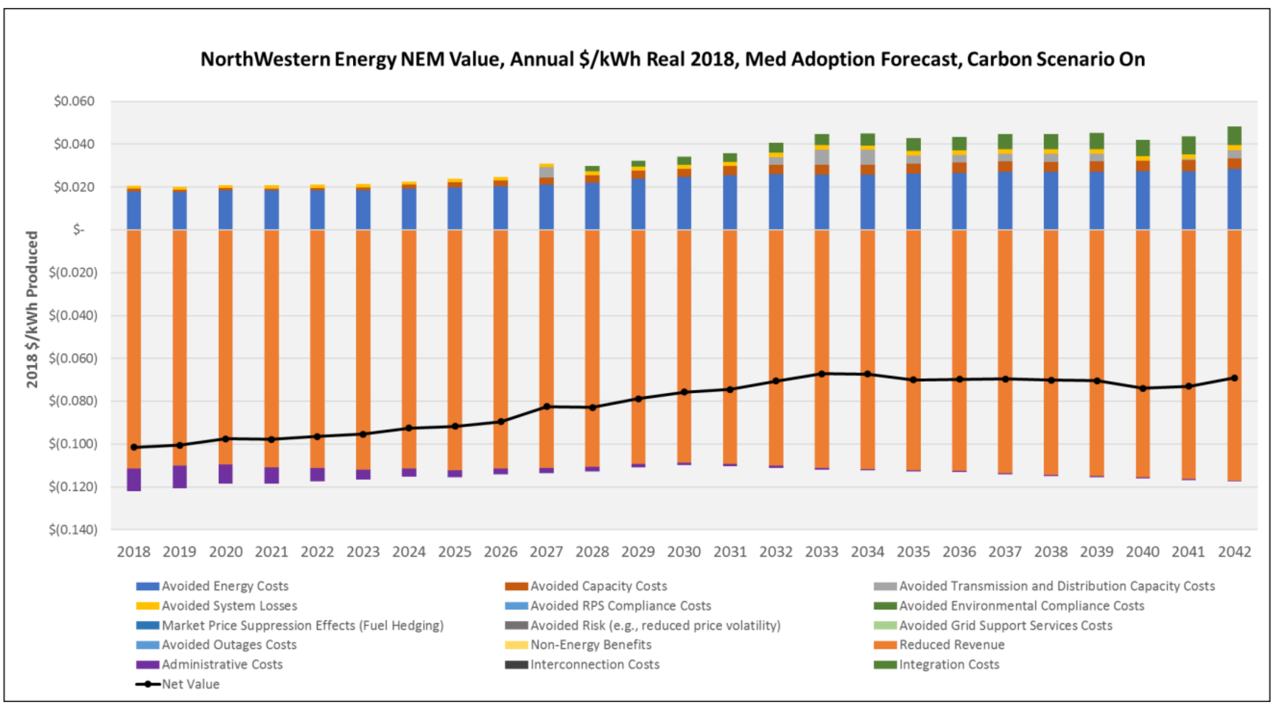


**Figure 19. Annual Net Value in Real $/kWh Based on UCT Test, High Adoption, Carbon On**

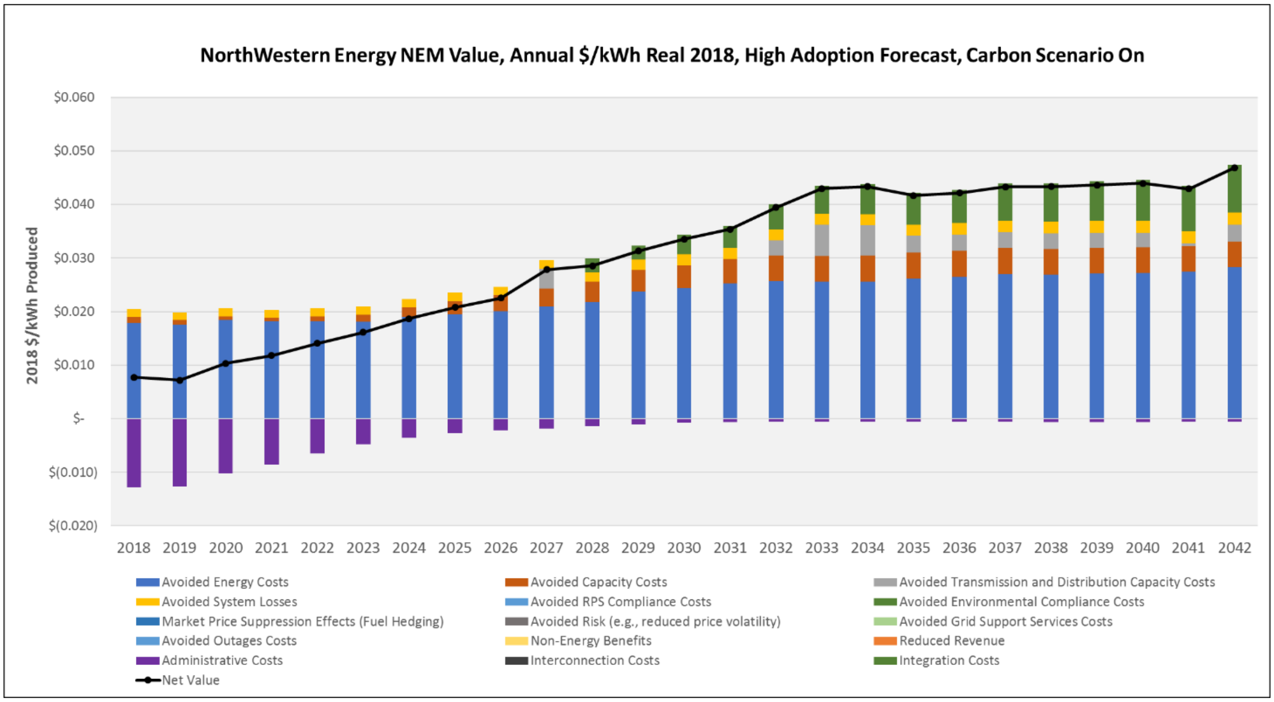



**Figure 20. Annual Net Value in Real $/kWh Based on RIM Test, High Adoption, Carbon On**