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Projections of Behind-the-meter Photovoltaic Adoption in NorthWestern Energy’s Montana Service Territory through 2050

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Foreword

The National Renewable Energy Laboratory (NREL) has developed a deep understanding of clean energy technologies and markets and has a long history of providing technical analysis and policy decision support to states. In order to respond to emerging state needs and help states understand the implications of state actions on advanced energy technology deployment, NREL conducts modeling and analysis of specific state-level energy policy actions.

The Solar Technical Assistance Team (STAT) Network is a project of the U.S. Department of Energy and is implemented by NREL. The purpose of STAT is to provide credible and timely information to policymakers and regulators for the purpose of solar technology-related decision support.

This analysis was conducted by the STAT Network at the request of the Montana Public Service Commission.

Project Description

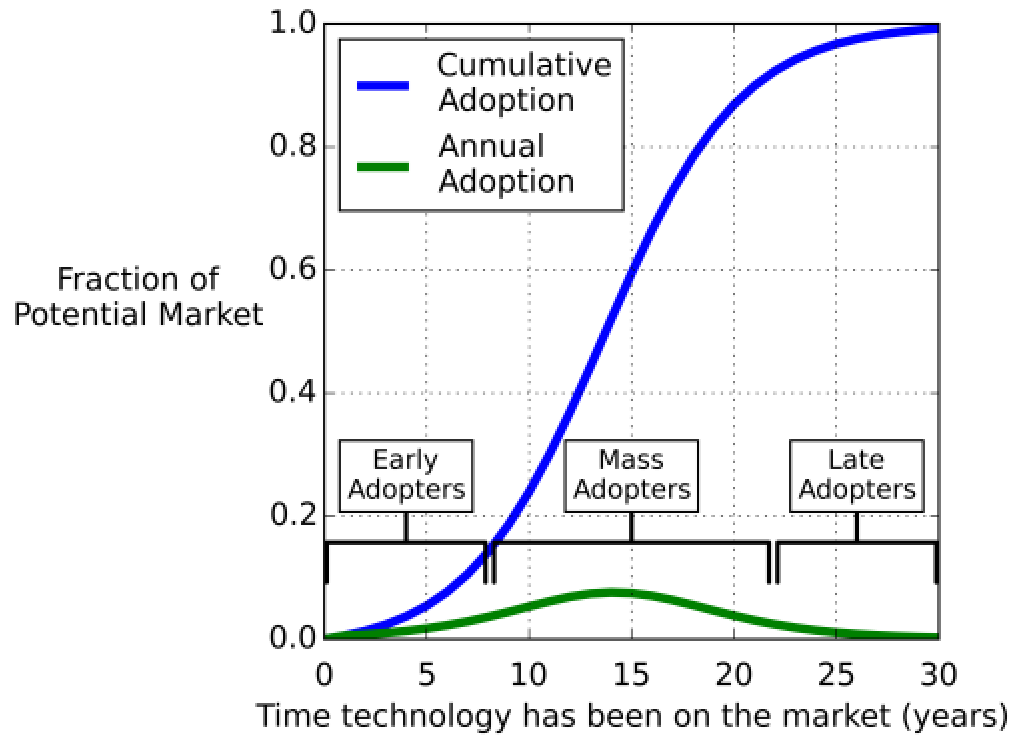
- NREL has used dGen (the Distributed Generation Market Demand Model) to project the adoption of Behind-the-meter PV (BTM PV) in NorthWestern Energy's Montana service territory through 2050.

- This presentation gives a high-level overview of the model and the analysis results. For complete documentation of the model, see *The Distributed Generation Market Demand Model (dGen): Documentation* (Sigrin et al. 2016).

dGen Model Description

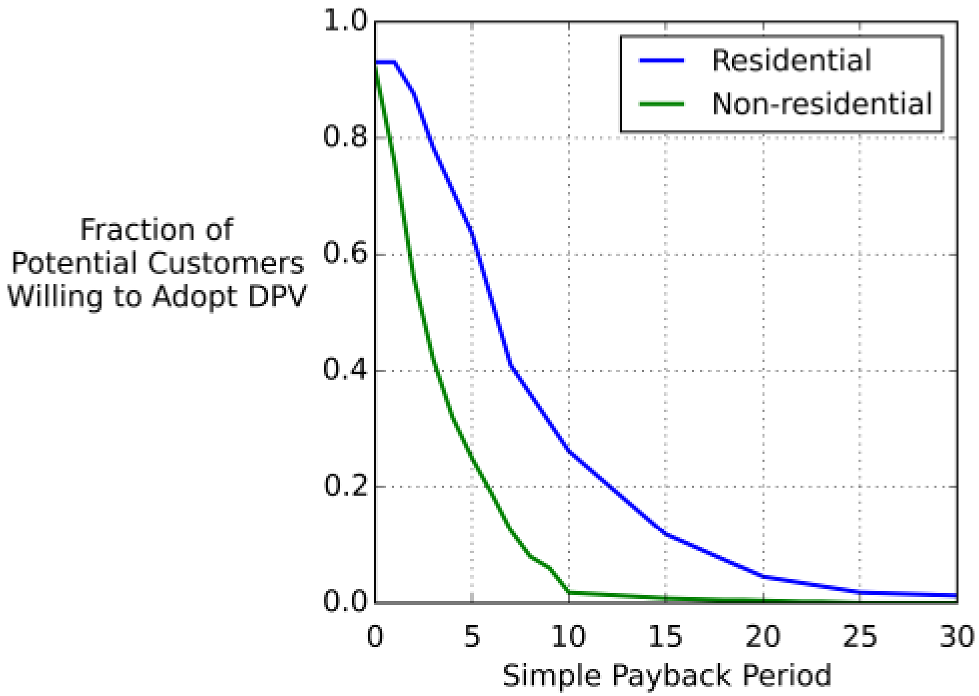
dGen Model Description

- The Distributed Generation Market Demand model (dGen) was developed by the National Renewable Energy Laboratory (NREL) as a tool to project the adoption of behind-the-meter PV in the continental United States.
- The framework captures commonly observed trends of how new technologies diffuse into a population with an "S-curve," as seen in the figure to the right.
- The curves shown are representative of the diffusion concept and are not the shapes used in this analysis.



dGen Model Description

- dSolar uses the curves shown to characterize the relationship between PV's economic attractiveness (payback period in years) and the fraction of a population that would be willing to purchase the technology.
  - *For example, with a 15-year payback, we predict 12% of possible residential customers and 1% of possible commercial and industrial customers would be willing to adopt solar PV.*
- These figures set the upper bound of the S-curve curve (in blue) of the previous slide. The model recalculates economic conditions for every two years in the forecast and adjusts the shape of the curve (and therefore the rate of diffusion) accordingly.
- This method reflects the fact that system cost is the primary driver of PV adoption while also capturing the non-economic considerations of customers.
  - *For example, even with long payback periods that would achieve lower rates of return than other potential investments, we would still expect a small percentage of possible customers to adopt PV. Conversely, even if the payback period is zero, we still would expect a small number of eligible customers to not adopt.*



Source for Residential data: *Diffusion into New Markets: Economic Returns Required by Households to Adopt Rooftop Photovoltaics* (Sigrin and Drury 2014)
Source for Non-residential data: *Rooftop Photovoltaics Market Penetration Scenarios* (Paidipati et al. 2008)

Scenario Definition and Model Assumptions

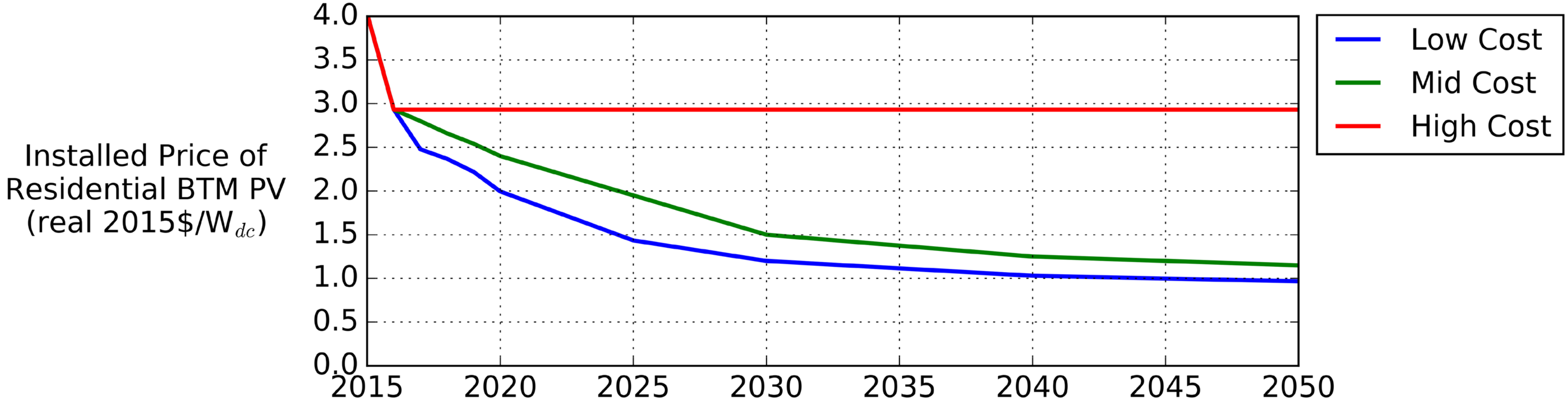
Scenario Definition

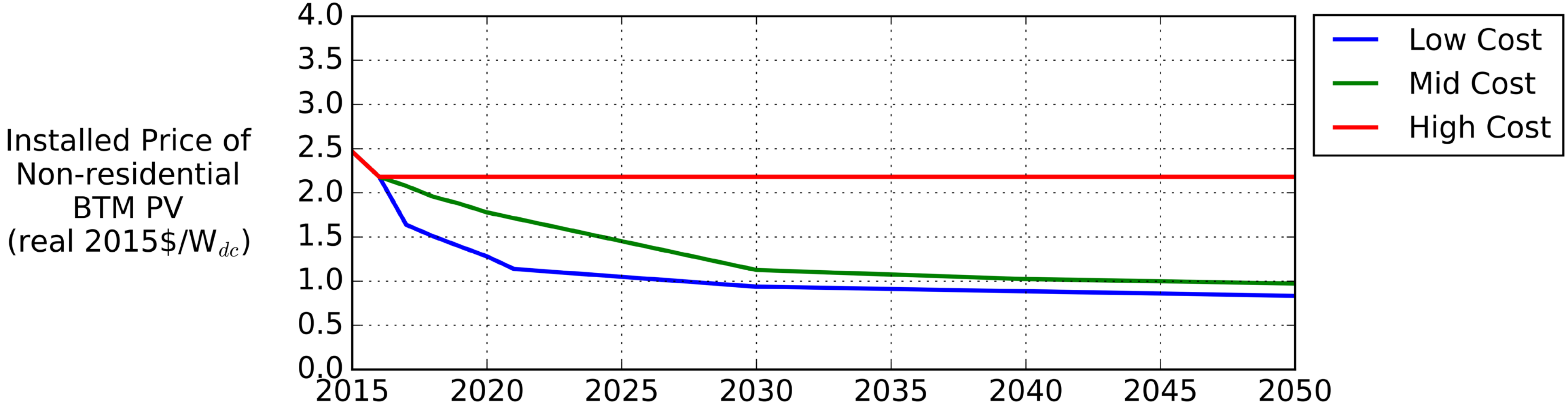
This analysis includes six scenarios, which differ in their assumption of the future price of PV, changes in the retail price of electricity, and the rate at which PV diffuses into the population of potentially interested customers.

- PV price trajectories are given on slide 9
- Electricity price trajectories are given on slide 10
- Rate of PV diffusion is discussed on slide 11
- Fixed assumptions that do not vary between scenarios are given on slides 12-13
- The definition of each of the six scenarios is given on slide 14

Technology costs

Future behind-the-meter PV price trajectories were obtained from NREL's 2017 Annual Technology Baseline (ATB) data set.[1]



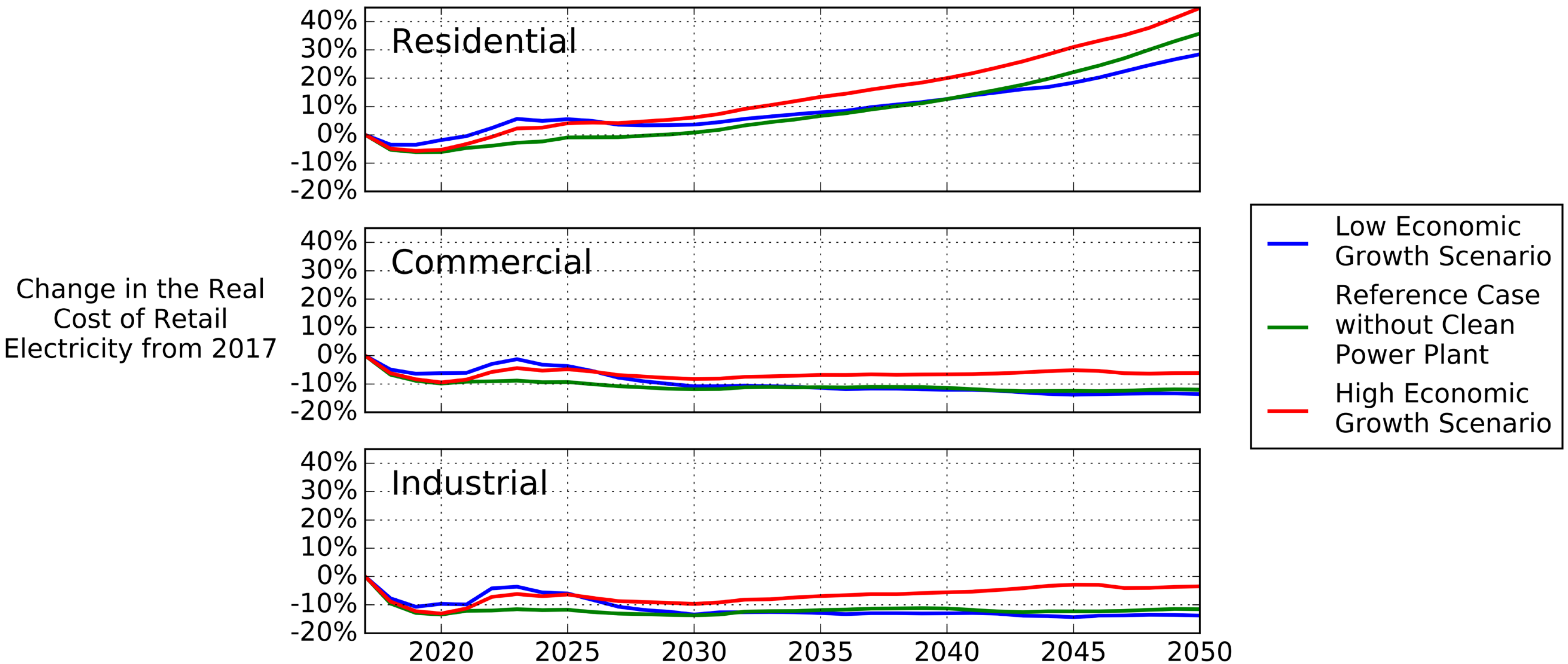


1. Actual modeled costs deviate slightly from these values on a county-by-county basis, according to a regional capital cost multiplier.

Electricity Prices

Electricity price changes were based off of projections from the EIA's 2017 Annual Energy Outlook, for the End-Use Price of Electricity in the Northwest Power Pool Area. The three scenarios given in the figure below were selected to represent the range of possible changes, where the High and Low Economic Growth scenarios represent the greatest and least changes in the cost of electricity by 2050, of the scenarios modeled in the Annual Energy Outlook.

Retail electricity tariffs were modeled as they were structured in NorthWestern's Montana service territory in November 2017. The BPA Exchange Credit and Universal System Benefits Charge were assumed to remain constant through 2050. The CTC-QF charges remained constant through June 2029, after which they were assumed to expire. All other tariff components were assumed to scale with the projected changes in the retail cost of electricity.



Rate of PV Diffusion

The rate that behind-the-meter PV is adopted is composed of two components: The rate at which the number of potentially interested customers is increasing as the financial performance of the investment increases, and the rate at which those potentially interested customers are actually adopting PV. The second term is referred to here as the rate at which PV is "diffusing" into the population of potentially interested customers.

Historical PV adoption trends in NorthWestern's service territory suggests that PV is diffusing into the potentially interested population of customers at a relatively slow rate, compared to the range of rates observed for other novel technologies. Therefore, this analysis includes scenarios where the rate of diffusion is estimated from historical adoption trends, and another "accelerated diffusion" set of scenarios where the rate of diffusion is set to a relatively rapid rate that have been observed for other technologies. The reference scenario uses a Bass "Q" parameter of approximately 0.3 (25-30 years to go from 5% diffusion to 95% diffusion), whereas the "accelerated diffusion" scenario uses a Bass "Q" parameter of 0.8 (8-10 years to go from 5% diffusion to 95% diffusion).

As illustrated in the results section of this analysis, the assumed rate of diffusion primarily affects near-term adoption. Long term (e.g., the installed capacity in 2050) adoption is primarily determined by the financial performance of PV, as it is assumed that the diffusion process will have mostly completed within that timeframe.

Assumptions Held Constant Across All Scenarios

General Assumptions:

- Customer counts, annual energy consumption trends, and projections of load growth followed data provided by NorthWestern Energy.
- Adoption in the residential sector is restricted to owner-occupied detached buildings.
- Maximum market shares are based on the market-share-versus-payback curves shown on Slide 4.
- Full retail net metering is assumed through the duration of the analysis. Current language in NorthWestern's net metering tariff indicates that the customer is responsible for the costs of all distribution and metering system modifications directly resulting from the installation and interconnection of the customer's generator (Interconnection Standards for Customer-owned, Net Metered, Grid-connected Electric Generating Facilities). However, due to the difficulty in projecting such costs, they were omitted from this analysis.

Financial Assumptions

- The financial performance of the PV systems were evaluated in terms of simple payback period, with incentives current to November 2017 were represented and bill savings were based off of the structure of NorthWestern Energy's Retail Electricity Tariffs.
- Five-year federal MACRS depreciation is available for non-residential customers. Residential customers do not depreciate systems.
- The federal investment tax credit is modeled according to law as of June 2017 (i.e., it phases down to 10% for non-residential customers and to 0% for residential customers by 2022).
- System financial performance was evaluated for a 20-year period, although estimates of production from installed systems assumed that systems remained operational throughout the study period with a constant rate of degradation.
- Inflation of 2.5%/year was assumed.

PV Technical Performance Assumptions

Characteristic	Value
System Size (Fixed)	Sized to provide 95% of annual consumption; constrained by 50 kW size limit for net metered systems
Module Type (Fixed)	Multicrystalline silicon
Module Power Density	160 W/m^2 in 2018, increasing to 220 W/m^2 by 2050
Tilt	Follows distribution of buildings characteristics in Montana observed in lidar data (Gagnon et. al. 2016)
Azimuth	Follows distribution of buildings characteristics in Montana observed in lidar data (Gagnon et. al. 2016)
Total System Electrical Losses (Fixed)	14%
Module Degradation (Fixed)	0.5%/year
Inverter Efficiency (Fixed)	96%
DC to AC Ratio (Fixed)	1.1

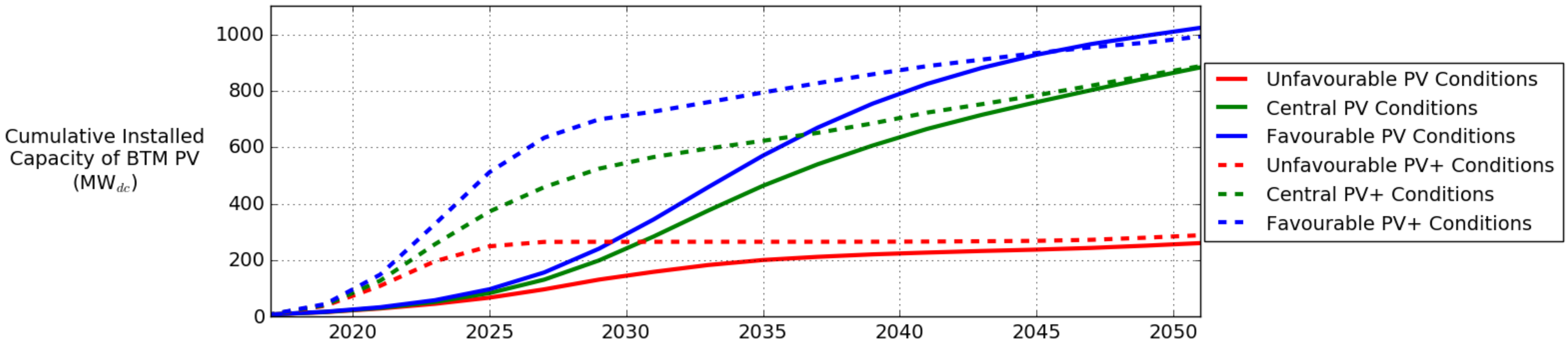
Scenario Definitions

Scenario Name	PV Price	Electricity Price	Rate of Diffusion
Unfavorable	High	Low Economic Growth (0.0% CAGR)	Historical
Central	Mid	Reference (0.1% CAGR)	Historical
Favorable	Low	High Economic Growth (0.3% CAGR)	Historical
Unfavorable +	High	Low Economic Growth (0.0% CAGR)	Accelerated
Central +	Mid	Reference (0.1% CAGR)	Accelerated
Favorable +	Low	High Economic Growth (0.3% CAGR)	Accelerated

Although these scenarios represent a wide range of possible BTM adoption as driven by the financial performance of BTM PV, they do not cover the entire possible range. In particular, policy changes could cause levels of adoption that are either less or greater than the results of this analysis.

Results

BTM PV Projections for NorthWestern Service Territory

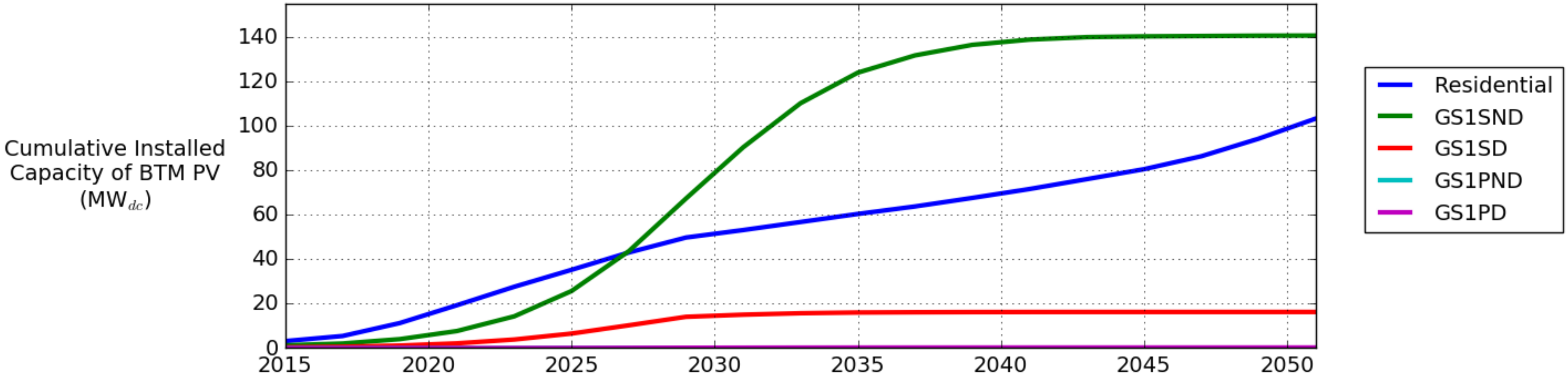


Cumulative BTM PV Capacity in NorthWestern (MW_{dc})

	2014	2016	2018	2020	2022	2024	2026	2028	2030	2032	2034	2036	2038	2040

- A separate NREL effort in 2016 estimated that there was 21 million square meters of roof area in the state of Montana that is technically suitable for hosting PV systems, which equates to a technical potential of 3.2 GW (3.9 TWh/year) for rooftop PV (Gagnon et al. 2016). Note that technical potential is expected to grow over the analysis period due to population growth, and this study only projected adoption within the NorthWestern service territory.
- Cumulative capacities are given for the end of the stated year, not the beginning

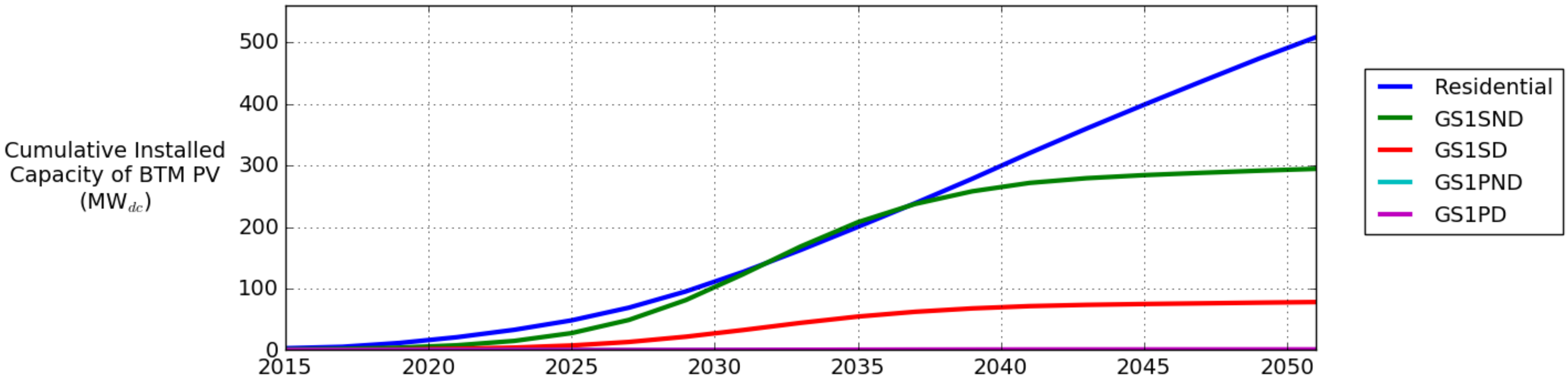
BTM PV Projections for the *Unfavorable* scenario



Cumulative BTM PV Capacity in NorthWestern (MW_{dc})

	2014	2016	2018	2020	2022	2024	2026	2028	2030	2032	2034	2036	2038	2040

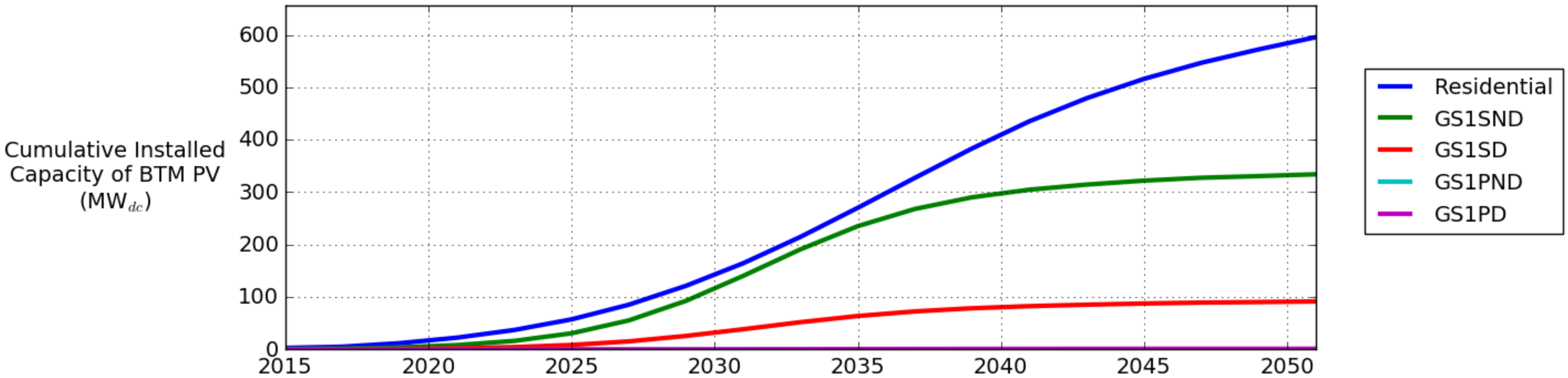
BTM PV Projections for the *Central* scenario



Cumulative BTM PV Capacity in NorthWestern (MW$_{dc}$)

	2014	2016	2018	2020	2022	2024	2026	2028	2030	2032	2034	2036	2038	2040

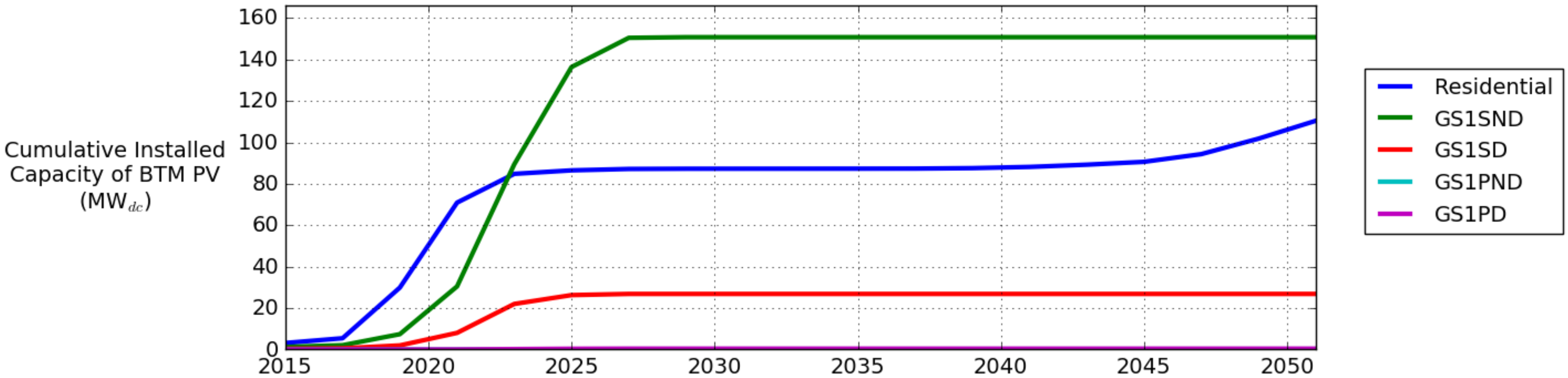
BTM PV Projections for the *Favorable* scenario



Cumulative BTM PV Capacity in NorthWestern (MW_{dc})

	2014	2016	2018	2020	2022	2024	2026	2028	2030	2032	2034	2036	2038	2040

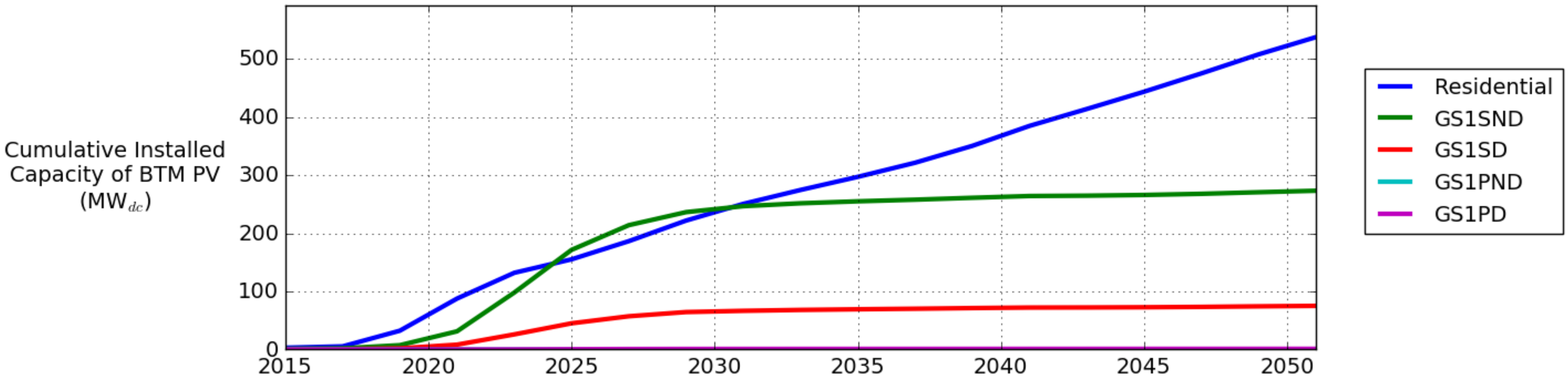
BTM PV Projections for the *Unfavorable +* scenario



Cumulative BTM PV Capacity in NorthWestern (MW_{dc})

	2014	2016	2018	2020	2022	2024	2026	2028	2030	2032	2034	2036	2038	2040

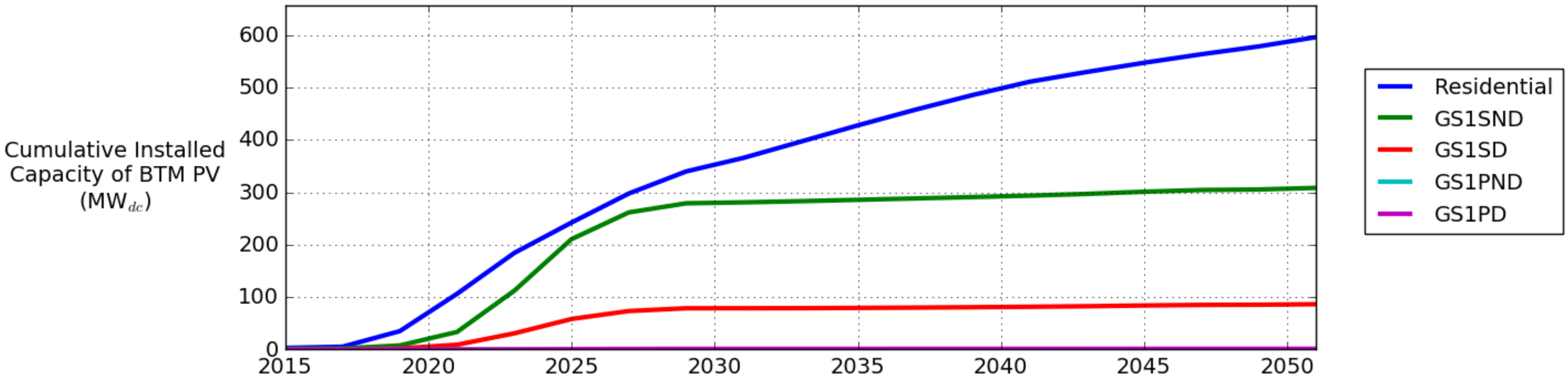
BTM PV Projections for the *Central +* scenario



Cumulative BTM PV Capacity in NorthWestern (MW_{dc})

	2014	2016	2018	2020	2022	2024	2026	2028	2030	2032	2034	2036	2038	2040

BTM PV Projections for the *Favorable +* scenario



Cumulative BTM PV Capacity in NorthWestern (MW_{dc})

	2014	2016	2018	2020	2022	2024	2026	2028	2030	2032	2034	2036	2038	2040

Appendix

History of NREL's State-Level Decision Support

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- Sigrin, B., and E. Drury. 2014. "Diffusing into New Markets: Economic Returns Required by Households to Adopt Rooftop Photovoltaics." *2014 AAAI Fall Symposium Series*.
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Nomenclature

AEO	Annual Energy Outlook
DPV	distributed photovoltaics
EKPC	Eastern Kentucky Power Cooperative
GWhac	…
LGE	Louisville Gas & Electric
KU	Kentucky Utilities
MACRS	Modified Accelerated Cost Recovery System
MW	megawatt
MWdc	megawatt, direct current
NREL	National Renewable Energy Laboratory
W/m^2	watts per square meter
yr	year

Thank you!

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