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Extended Motor Products Variable Load Baseline and Constant-Load to Variable Load Savings Key Assumptions Review

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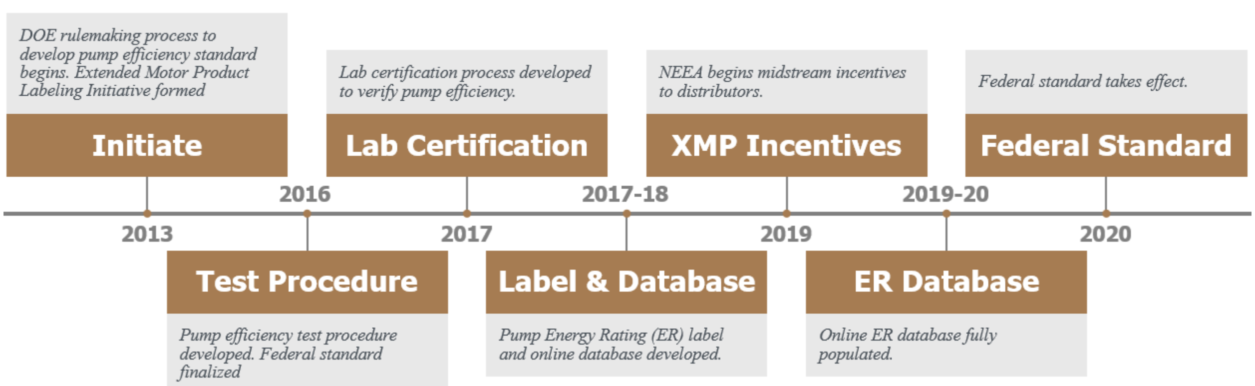
1. Introduction

This report presents findings from Apex Analytics' review of NEEA's baseline assumptions and savings calculation approach for variable speed pumps, which are part of the Extended Motor Products (XMP) market transformation program. NEEA sought an independent review of its approach to estimating a natural market baseline for adoption of variable speed pumps and its approach to estimating energy savings attributable to installation of variable speed drives on commercial and industrial pump systems.

To raise market awareness and enable product differentiation, NEEA's XMP program partners with industry groups to develop and influence energy labeling programs. To motivate distributors to preferentially stock and sell efficient products, NEEA provides midstream incentives and other support. In exchange, distributors supply NEEA with full-category sales data, which informs program strategy and enables the market progress to be measured. Ultimately, these market interventions are intended to accelerate market diffusion and the adoption of efficient pump products, supporting NEEA's ability to influence the passage of more effective federal standards. The program's initial focus has been on commercial and industrial pumps; NEEA's efforts related to pumps began in 2013, when DOE began a rulemaking process to develop federal efficiency standards for commercial and industrial pumps. NEEA contributed to the rulemaking process and worked with other efficiency organizations and industry groups to develop test procedures, a lab certification process, the Pump Energy Rating (ER) label, and an online pump efficiency database. NEEA also began working with pump distributors in the Northwest, providing midstream incentives for sales of efficient pumps and gathering sales data. Figure 1 summarizes these activities.

Figure 1: XMP Program Timeline



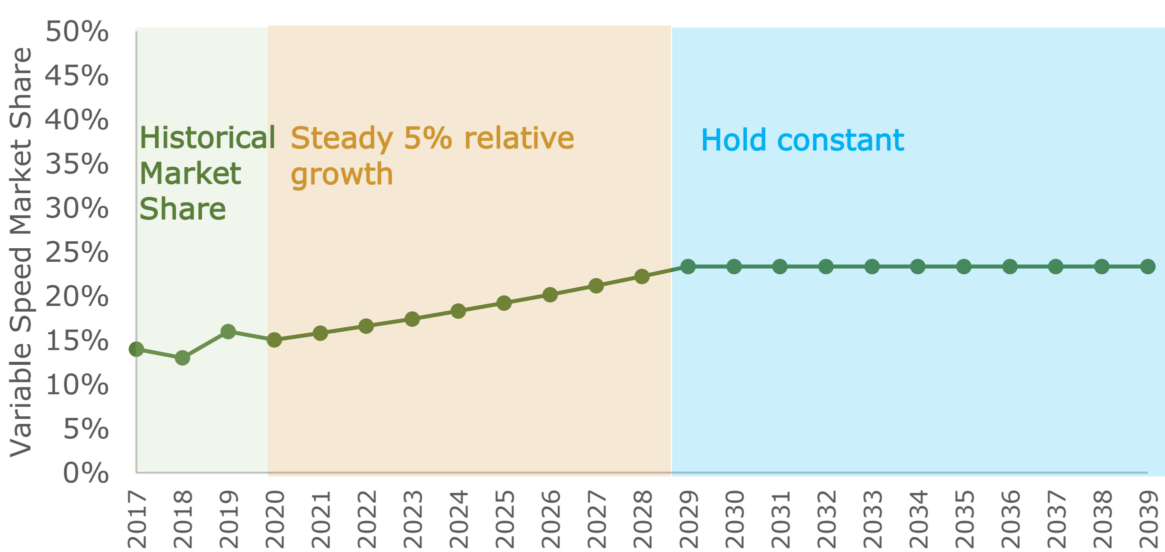
2. Baseline Approach

2.1 Background

To help assess the influence of its programs on the markets for efficient products, NEEA develops naturally occurring market share baseline estimates that forecast uptake of efficient products in the absence of intervention from NEEA or its utility partners. NEEA proposes to begin its naturally occurring baseline market share forecast in 2020. This timing corresponds with the launch of the program's midstream incentives for efficient pumps. While the incentives were first offered in 2019, only one distributor participated in the program's first year; by 2020 participating distributors represented a larger share of the market.

NEEA's proposed baseline forecasts for variable speed pumps set a starting market share value based on a three-year average of the market shares for 2017-2019 calculated from the market data provided by participating distributors. NEEA's proposed approach assumes market share will grow steadily from this starting value at a relative rate of 5% per year, based on uptake projections from the 2015 Technical Support Document (TSD) developed as part of the U.S. Department of Energy's (DOE) rulemaking process to develop federal efficiency standards for pumps.[1] Recognizing the uncertainty of projecting into the future from limited historical data, NEEA holds its baseline estimate constant from 2030 on. Figure 2 illustrates this baseline estimate.

Figure 2: NEEA Proposed Variable Speed Pumps Baseline Market Share Forecast



[1] Navigant Consulting and Lawrence Berkeley National Laboratory, "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial and Industrial Pumps" (U.S. Department of Energy, March 2015), https://www.regulations.gov/document/EERE-2011-BT-STD-0031-0039.

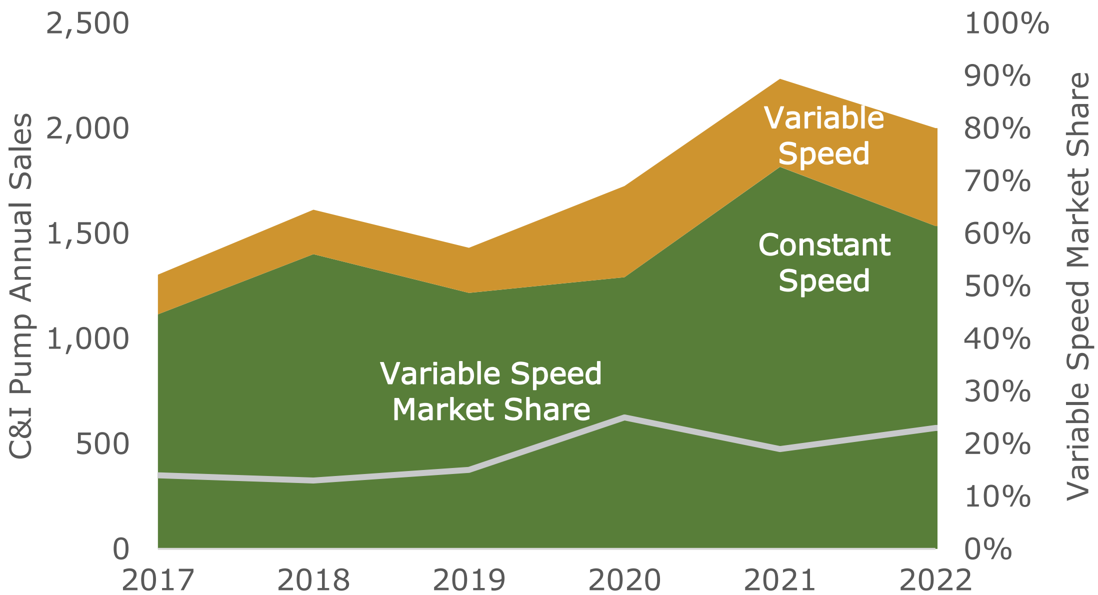
2.2 Assessment

Apex assessed three components of NEEA's baseline estimate for variable speed pumps: the starting market share, the rate of growth, and the threshold at which the baseline projection flattens.

Beginning Market Share

NEEA uses a three-year historical average of variable speed market shares for 2017-2019 to set the starting point for its proposed baseline market share forecast. Apex reviewed sales data that participating distributors provided to assess this approach. The Bonneville Power Administration's (BPA) Industrial Adjustable Speed Drives Northwest Market Model notes that pump sales can vary a great deal from year to year, since construction of a few large facilities can cause a temporary spike in sales.[2] NEEA's sales data is consistent with this finding, with overall pump sales varying from year to year. As Figure 3 shows, variable speed pump market share was largely flat from 2017-2018, with a slight increase in 2019 and a larger jump in 2020. Market shares declined in 2021 to a level more consistent with their previous trend before continuing growth at a more steady pace in 2022.

Figure 3: Pump Sales and Variable Speed Market Share 2017-2022



[2] Nathan Baker et al., "Industrial Adjustable Speed Drives Northwest Market Model" (Portland, OR: Bonneville Power Administration, July 2022), https://www.bpa.gov/energy-and-services/efficiency/market-research-and-momentum-savings/adjustable-speed-drives-market-research.

The jump in market share in 2020 occurred across pump size bins, distributors, and manufacturers. As a result, it likely reflects a market-wide influence. Two events in 2020 may have contributed to this jump in market share:

- **The federal standard taking effect:** The federal standard for pumps, adopted in 2016, took effect in 2020. While it did not directly mandate variable speed pumps, the standard changed the range of options available to pump buyers, potentially leading more of them to select variable speed options.
- **The Covid-19 pandemic:** The pandemic impacted markets in a wide variety of ways, changing the extent to which facilities were willing – and the types of facilities willing – to invest in equipment, as well as the availability of equipment and contractors or staff members able to install it.

Recommendation:

- **NEEA should use a linear forecast based on historical sales data from the three years prior to the start of its forecast rather than a three-year average, as the pre-intervention market share in its baseline forecast.** This approach would allow the forecast to incorporate any trends in uptake prior to NEEA's intervention.[3] In the case of variable speed pumps, this would include the slight increase in market share observed in 2019.
- **NEEA should assess the extent to which the spike in variable speed market share in 2020 reflected XMP efforts.** From a long-term perspective, the spike in market share in 2020 may not have a large impact on NEEA's baseline estimates. Variable speed market shares returned to a level closer to their previous trend in 2021. In addition, some portion of the spike is likely attributable to program activities, particularly to the extent that the spike was caused by the federal standard, which NEEA influenced through its submittal of comments and analysis, participation in working groups, and negotiations with manufacturers,[4] taking effect. Nonetheless, it may be worthwhile for the program to better understand the causes of the spike in variable speed market share in 2020 in order to better assess short-term market effects.

Growth Rate

As noted above, NEEA's proposed approach assumes a relative annual growth rate of 5% for the market share of variable speed pumps, based on the 2015 TSD developed for the federal standard rulemaking completed in 2016. The document's authors derive that 5% growth rate from manufacturer survey responses that estimate variable speed market share

[3] A multi-year average approach will produce a value that is lower than the final pre-intervention year if market share is trending up or higher than the final pre-intervention year if market share is trending down, thus reversing the observed trend. In contrast, a linear forecast will continue the observed trend. If there is not a clear trend in market share in the pre-intervention period, the two approaches will likely produce similar results.

[4] Rupam Singla, Marian Goebes, and Yamini Arab, "Commercial and Industrial Pumps Standard Evaluation" (Portland, OR: Northwest Energy Efficiency Alliance, May 3, 2021), https://neea.org/resources/commercial-and-industrial-pumps-standard-evaluation.

to be between five and ten percent and a 1998 study that found that 3.2% of pumps were variable speed.[5]

DOE has since published a more recent TSD to support an ongoing rulemaking to update pump efficiency standards.[6] This newer document revises its estimates of market share growth for variable speed pumps to an absolute annual increase of 0.665%. This estimate is based on the same 1998 study cited above as well as a newer Industrial and Commercial Motor Systems Market Assessment Report (MSMA), published in 2021.[7] The 2021 MSMA finds that 21% of industrial pumps are variable speed and 16% of commercial pumps are variable speed. The 0.665% annual growth rate reflects linear growth from 3.2% penetration in 1998 to 18.5% penetration – the midpoint of the commercial and industrial values – in 2021.

There are a few inconsistencies in the recent TSD's approach, however.

- Rather than reflecting a snapshot of the market in 2020, the 2021 MSMA was based on data collected over a three-year period, from 2016 to 2019. Data for the 1998 study were collected over 10 months in 1997.
- The 3.2% penetration figure found in the 1998 study reflected only industrial facilities. As a result, it may not be an accurate comparison for a combined commercial and industrial share.
- Both the 1998 study and the 2021 MSMA were based on surveys of installed pumps, rather than pump sales. If, as these studies suggest, the installed stock of variable speed pumps is increasing, the share of pumps sold that include variable speed drives (VSDs) is likely greater than the share of VSDs installed.

Apex recalculated the growth rate of variable speed pumps in industrial facilities to address the first two inconsistencies listed above. We assumed that the 3.2% penetration from the 1998 study reflects the share of industrial variable speed pumps in the middle of 1997, and that the 21% penetration from the 2021 MSMA reflects the share of industrial variable speed pumps in the middle of 2017 – the midpoint of the data collection period. This suggests an absolute annual growth rate of 0.89%, or a relative growth of 9.86%, in uptake of variable speed pumps in industrial facilities. Apex was unable to find an earlier source

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[5] Xenergy, Inc., "United States Industrial Electric Motor Systems Market Opportunities Assessment" (Washington, DC: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, December 1998), https://www.energy.gov/sites/prod/files/2014/04/f15/mtrmkt.pdf.

[6] Guidehouse and Lawrenece Berkeley National Laboratory, "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Pumps" (U.S. Department of Energy, August 2022), https://www.regulations.gov/document/EERE-2021-BT-STD-0018-0013.

[7] Prakash Rao et al., "U.S. Industrial and Commercial Motor System Market Assessment Report Volume 1: Characteristics of the Installed Base" (Berkeley, CA: Lawrence Berkeley National Laboratory Energy Technologies Area, January 2021), https://eta-publications.lbl.gov/sites/default/files/u.s._industrial_and_commercial_motor_system_market_assessment_report_volume_1-_characteristics_of_the_installed_base_p_rao.pdf.

estimating variable speed pump market share in commercial facilities, so we cannot make a similar calculation for commercial pumps.

The Bonneville Power Administration's (BPA) Industrial Adjustable Speed Drives Northwest Market Model provides another estimate of baseline growth in industrial variable speed drive market share in the region.[8] The model's baseline approach differs somewhat from NEEA's approach in that it assumes market saturation will remain constant at its 2015 level (the year the Northwest Power and Conservation Council's Seventh Power Plan was adopted). Changes in baseline saturation over time reflect only changes in the distribution of motors serving variable loads versus constant loads, which, in turn, is driven by changes in the composition of the region's industrial customer base.[9] The BPA market model's estimates anticipate baseline saturation growing from 38% in 2014 to 44% in 2021, an absolute annual growth rate of 0.9% over that period, which is consistent with the recalculated growth rate from the national studies

Apex reviewed the sales data distributors submitted to the XMP program as an additional source of data on baseline market trends but found that market volatility from year to year, combined with the relatively short period of baseline data available (three years) made it impossible to identify any ongoing trends in uptake of variable speed pumps.

Recommendations:

- **NEEA should adopt an absolute annual growth rate of 0.9% for variable speed market share, rather than its proposed 5% relative annual growth rate, until the market reaches a natural ceiling for variable speed market share or market data suggest continued linear growth is no longer appropriate.** Both the recalculated growth rate adapting the TSD methodology and BPA's Northwest Market Model suggest absolute annual baseline growth rates of approximately 0.9%. It is important to note that both of these studies may underestimate growth in market share of variable speed pumps sold. Both estimates reflect change in installed stock, rather than sales, and the Northwest Market Model accounts only for changes in the composition of industrial facilities, not any push to improve building energy performance due to energy rating and disclosure requirements or other causes. Nonetheless, the effect of these factors on market share is difficult to quantify.
- **NEEA should conduct additional research focused on uptake of variable speed pumps in commercial buildings and understanding relationships between installed stock and market share.** As noted above, the 2021 MSMA was the only source Apex found that specifically addressed pumps in commercial buildings. It found that the saturation of variable speed pumps was lower in commercial buildings than in industrial facilities but does not provide insight into whether the rate of adoption of variable speed pumps, and thus variable speed market share, is likely to be different in commercial facilities relative to industrial facilities. All of the existing sources that Apex reviewed also assessed variable speed pumps as a share of the installed stock, rather than as a

[8] Baker et al., "Industrial Adjustable Speed Drives Northwest Market Model."

[9] It is also important to note that the Regional Market Model normalizes market share by pump motor horsepower.

market share of pumps sold. An increase in the installed stock implies growth in market share, but the relationship between the two metrics is complex.

Market Share Threshold

NEEA's proposed baseline approach flattens the predicted market share beginning in 2030, when it is projected to be 23%. Apex investigated additional factors that might provide upper limits for baseline market share. Specifically, NEEA staff suggested that, in a baseline scenario, commercial and industrial customers would be unlikely to install variable speed pumps in constant load applications. While variable speed pumps can provide energy savings in constant load applications by ensuring the pump's power matches its load precisely, variable speed pumps provide greater energy savings in variable load applications. As a result, end-users would be less likely to select variable speed pumps for constant load applications without program intervention.

Apex reviewed Commercial Building Stock Assessment (CBSA) data to identify the share of pumps installed in the Northwest likely to serve variable loads. Apex staff classified the listed pump functions as likely constant load or variable load based on their professional experience.[10] Based on these classifications, we estimate that 41% of pumps installed in commercial facilities in the Northwest are likely to serve variable loads. This is consistent with estimates from the Northwest Market Model, which drew on data from the recent MSMA to estimate that 45% of pumps in industrial facilities in the Northwest serve variable loads.[11]

Recommendation:

- **NEEA should regularly reassess whether market conditions justify continued baseline growth or a plateau in baseline market share.** NEEA's proposed approach flattens the predicted baseline market share beginning in 2030, holding the baseline market share forecast constant at 23%. This decision is based on NEEA's recognition that projections based on limited historical data become increasingly uncertain the farther they are extended into the future. While NEEA's concern about forecasting from limited historical data is valid, this review did not find market data to justify 23% as a market share ceiling for variable speed pumps. Instead, market data suggest a variable speed market share ceiling closer to 40% in a baseline scenario.[12] At the recommended 0.9% annual growth rate, it would take until 2046 for baseline market share to reach that ceiling. As NEEA's approach recognizes, there is a great deal of potential for naturally occurring shifts in the pump market prior to 2046 that would impact variable speed market share. As a result, NEEA should monitor the pumps market for these naturally occurring shifts (for example, changes in production costs or shifts in prevalence of different types of commercial and industrial pump users in

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[10] A table listing our classifications is included as an appendix to this memo.

[11] Baker et al., "Industrial Adjustable Speed Drives Northwest Market Model."

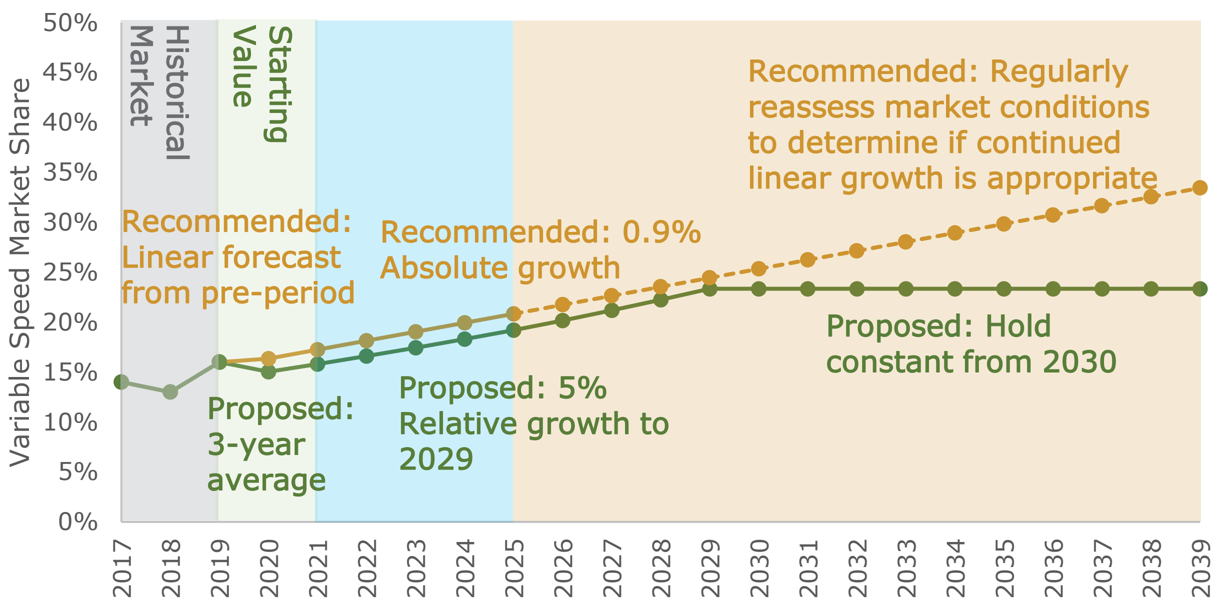
[12] NEEA's assumption that commercial and industrial customers would install variable speed pumps only in variable load applications in a baseline scenario is reasonable, and available data suggest that approximately 40% of commercial and industrial pumps in the Northwest serve variable loads.

the Northwest) and determine whether a continued linear baseline market share is appropriate, or if it would be more accurate to flatten or otherwise adjust the baseline. NEEA could conduct formal reviews to assess market conditions every five years, beginning in 2025, or as needed in response to market changes. NEEA should also consider conducting additional research, including outreach to market actors like manufacturers, to determine what factors other than the share of pumps that serve variable loads could limit variable speed market share or cause shifts in baseline market share trends.

2.3 Recommended Approach

Figure 4 illustrates both NEEA's proposed baseline forecast and the baseline forecast that would result from adopting each of the recommendations described above.

Figure 4: Recommended Baseline Forecast



3. Constant-to-Variable Load Savings Review

3.1 Background

NEEA's proposed approach to calculate the energy savings attained from adding a variable-speed drive (VSD) to an existing pump is based on the energy savings values for VSDs the Northwest Regional Technical Forum (RTF) developed. The RTF estimates were based on an analysis of metered data of pumps with variable speed drives.[13] NEEA's proposed approach modifies the RTF savings estimates in two ways:

- NEEA applies a 9% reduction in savings to account for the current market share of VSDs in new pump installations
- While the RTF's savings estimation approach was designed for pumps 20 horsepower (hp) or less, NEEA applies it to pumps up to 200 hp.

3.2 Assessment

Apex assessed NEEA's VSD pump savings assumptions relative to regional Technical Reference Manuals (TRMs) and the savings estimates produced in the BPA Industrial Adjustable Speed Drives Northwest Market Model.[14]

TRM Comparison

Apex reviewed savings estimation approaches for variable speed pumps used in other jurisdictions to assess whether NEEA's proposed savings approach provides comparable savings estimates. Apex included commonly used technical reference manuals (TRMs) from Illinois, Indiana, Massachusetts, California, Arkansas, Pennsylvania, and the Mid-Atlantic in this comparison. Neither the California nor the Arkansas TRM included any measures that would be comparable to XMP, while the Pennsylvania and Mid-Atlantic TRMs use custom savings calculations that rely on a significant amount of site-specific data. This assessment ultimately compared the deemed kWh/HP savings values utilized by XMP to the outputs of the algorithms used in the Illinois, Indiana, and Massachusetts TRMs when controlling for various parameter inputs.

Apex limited the savings analysis by comparing similar end uses to ensure the most accurate comparisons between the XMP and the various TRMs. Only the Indiana TRM had a measure that is comparable to cooling towers, while the Massachusetts TRM had two measures that could be considered comparable to heating pumps. The full alignment of the end uses from the XMP and the TRMs are presented in

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[13] Cadmus, "Power Drive Systems: Energy Savings and Non-Energy Benefits in Constant & Variable Load Applications" (NEEA, June 2020), https://neea.org/resources/power-drive-systems-energy-savings-and-non-energy-benefits-in-constant-variable-load-applications.

[14] Baker et al., "Industrial Adjustable Speed Drives Northwest Market Model."

Table 1.

Table 1: Alignment of end-uses between XMP and TRMs

<table>
<tr><th>XMP</th><th>Illinois*</th><th>Massachusetts**</th><th>Indiana***</th></tr>
<tr><td>**Cooling**</td><td>Chilled Water Pump</td><td>Chilled Water Pump</td><td>Chilled Water Pump</td></tr>
<tr><td>**Cooling Tower**</td><td>NA</td><td>NA</td><td>Circulating Water Pump</td></tr>
<tr><td rowspan="2">**Heating**</td><td rowspan="2">Hot Water Pump</td><td>Boiler Feed Water Pump</td><td rowspan="2">Hot Water Pump</td></tr>
<tr><td>Hot Water Circulating Pump</td></tr>
<tr><td colspan="4">*This measure is not applicable for Cooling towers, chilled or hot water pumps with any process load.
**Prescriptive Incentives will be provided for the installation of Variable Speed Drives (VSD) from 1-150hp for ONLY the following installation types: Chilled and Condenser Water Distribution Pump [CWP], Boiler Feed Water Pump [FWP], Water Source Heat Pump Circulation Pump [WHP], Heating Hot Water Pump [HWP], Process Cooling Pump [PCP]. All other VSD applications MUST file a Custom Application</td></tr>
</table>

The analysis also accounted for the various building types referenced in other TRMs. XMP distinguishes the types of buildings where VSDs may be installed only by broad market sectors (Agricultural, Industrial, Municipal, and Commercial – comprised of cooling, cooling tower, heating, and pressure boost applications). Other TRMs differentiate between building types to a much greater extent than the XMP program: the Indiana TRM cites three different building types, the Massachusetts TRM cites 10 different building types, and the Illinois TRM cites 25 distinct building types. The comparisons provided in this analysis reference the range (high, low, median, mean) of estimates attributed to the various building types.

Table 2 presents a comparison of the XMP saving estimates by application, compared to the median value calculated for comparable applications in the reviewed TRMs. In most instances the deemed savings value from the XMP is significantly lower than comparable median estimate from each respective TRM, save for cooling (chilled water) pumps from the Illinois TRM. A detailed discussion of each comparison and the full range of calculated values is provided as an appendix to this memo.

Table 2: Comparison of VSD Savings Estimates to Median TRM Values

<table>
<tr><th colspan="2">XMP</th><th colspan="2">Illinois</th><th colspan="2">Massachusetts</th><th colspan="2">Indiana</th></tr>
<tr><th>Application</th><th>Savings Estimate</th><th>Comparable Application</th><th>Savings Estimate</th><th>Comparable Application</th><th>Savings Estimate</th><th>Comparable Application</th><th>Savings Estimate</th></tr>
<tr><td>Cooling</td><td>**415 kWh/HP**</td><td>Chilled Water Pump</td><td>**182 (44%)**</td><td>Chilled Water Pump</td><td>**1,305 (315%)**</td><td>Chilled Water Pump</td><td>**6,655 (1605%)**</td></tr>
<tr><td>Cooling Tower</td><td>**180 kWh/HP**</td><td>NA</td><td>-</td><td>NA</td><td>-</td><td>Circulating Water Pump</td><td>**951 (529%)**</td></tr>
<tr><td rowspan="2">Heating</td><td rowspan="2">**365 kWh/HP**</td><td rowspan="2">Hot Water Pump</td><td rowspan="2">**868 (238%)**</td><td>Hot Water Circulating Pump</td><td>**2,067 (566%)**</td><td rowspan="2">Hot Water Pump</td><td rowspan="2">**6,146 (1682%)**</td></tr>
<tr><td>Boiler Feed Water Pump</td><td>**1,990 (545%)**</td></tr>
</table>

In most instances the savings estimation approach proposed for XMP derives significantly lower savings than comparable estimates from each respective TRM, save for cooling (chilled water) pumps from the Illinois TRM. While the cooling pump estimates from the Illinois TRM are consistently lower than NEEA's proposed savings values for XMP, the Illinois calculations rely on a number of assumptions, namely motor efficiency and energy savings factor. Using slightly lower estimates for motor efficiency, or slightly higher values for energy savings factor, would bring the Illinois TRM cooling values more in line with the XMP estimates.

One of the two TRMs included in the savings comparison that provide deemed savings values for kWh/HP (Massachusetts) included the source of the values. This source was from a study published 13 years ago, based solely on modeled data. The source of deemed values in the Indiana TRM was not provided. NEEA's proposed XMP savings are more general than these TRMs, as they do not segment by building type (including estimated hours of operation) or specific end use application. The TRMs that rely on more custom savings calculations also all include substantial variation contingent upon the input variables, which XMP's broad approach does not capture.

Overall, NEEA's proposed savings estimates for variable speed pumps are generally conservative relative to similar measures from other commonly used TRMs. This likely reflects the more general nature of XMP estimates, while other TRMs account for a wider range of building types, operational hours, and specific end uses. The RTF savings estimates on which NEEA's proposed approach is based were unique among the reviewed approaches in that they draw on primary data collection within the covered territory. As a result, they may also be more accurate than approaches based solely on modeling or secondary data.

Northwest Market Model Approach

The Northwest Market Model also developed savings estimates for industrial pumps. The model developed an algorithm to calculate pump energy consumption that would apply to a broader scope of pumps than the existing RTF savings estimates and that allowed for calculation of savings on both variable load and constant load systems.[15] While the market model is limited to industrial pumps, it is a potentially valuable source to inform NEEA's savings estimates since it is both Northwest-focused and takes a broader, market-level view that is more consistent with NEEA's market transformation approach than many of the reviewed TRMs.

Apex reviewed the resulting energy consumption estimates and used them to calculate energy savings estimates for comparison against NEEA's proposed kWh/hp values. Apex used the following assumptions from the market model spreadsheet to calculate average unit energy savings values from the spreadsheet's listed unit energy consumption values:

- equipment type = "Pumps"
- equip vintage = across all vintages
- facility type = calculated for each facility type, then averaged across types
- load type = constant, variable

[15] Baker et al.

The resulting savings for each grouping were calculated from the difference between control strategy of "Adjustable Speed Drive (ASD) Control" relative to "No ASD Control" and are summarized in

Table 3 below.[16]

Table 3. BPA Market Model Industrial VSD UES per HP relative to NEEA XMP Industrial VSD

Source	Load	Metrics	Motor Size					
			1-5HP	6-10HP	11-20HP	21-50HP	51-100HP	101-200HP
BPA MM	Constant	Minimum	365	389	499	506	613	637
BPA MM	Constant	Maximum	548	583	638	647	743	772
BPA MM	Constant	Average	465	495	557	566	681	707
BPA MM	Variable	Minimum	631	648	798	812	977	1,007
BPA MM	Variable	Maximum	947	972	1,020	1,038	1,185	1,221
BPA MM	Variable	Average	804	826	892	907	1,086	1,119
NEEA XMP	N/A	Average	491	491	491	491	491	491

With the exception of pumps 5 HP and below serving constant loads, NEEA's kWh/hp estimate is lower than the savings values resulting from the market model estimates. The market model estimates also show a clear trend of increasing kWh/hp savings as horsepower bins increase. NEEA's approach, in contrast, holds the kWh/hp savings value constant across horsepower bins. The analysts who developed NEEA's assumptions noted that they could not identify a strong correlation between kWh/hp and horsepower.

[16] The Market Model refers to "adjustable speed drives" (ASDs) as a broader category of devices that can vary the speed of a motor, of which variable speed drives are the most common type. ASDs also include motor technologies that provide inherent variable speed capabilities, like synchronous reluctance motors.

3.3 Recommendations:

- **NEEA should consider whether incorporating additional facility-level information into its savings estimates for variable speed pumps would allow for higher savings estimates with greater confidence for certain installations and assess the feasibility of gathering those more granular data.** XMP's proposed savings approach results in lower savings estimates than the approaches in the reviewed TRMs, which account for more building specific and end-use specific details. If certain facility types and end-use types result in notably higher savings than others, taking a similarly granular approach may allow NEEA to report more energy savings than its proposed, broad approach allows. However, most of the reviewed TRMs were developed for downstream programs, in which a great deal of information is available about the facility where a pump is installed. As a market transformation program that primarily operates at the midstream level, XMP does not have access to the same level of granular detail for each pump installation. XMP cannot base its energy savings estimates on custom project details, but must use market averages or other assumptions of common market characteristics. NEEA should ensure its savings estimation approach balances sufficient granularity to accurately reflect the program's energy savings accomplishments, with sufficient generality to reflect the program's market transformation focus.

NEEA should reassess whether there is a correlation between pump horsepower and kWh/hp savings. The Northwest Market Model analysis showed a clear pattern of increasing unit energy savings as pump horsepower bins increased, and savings estimates for larger horsepower pumps in particular well exceeded NEEA's estimates. NEEA should further consider whether model input data are available to apply the Northwest Market Model's savings approach to commercial, municipal, and agricultural pumps, and whether any adjustments to the algorithm would be necessary to account for differences between pumps in these sectors and in the industrial sector.

Appendix 1: Detailed TRM Comparisons

Illinois TRM

Illinois TRM measure 4.4.17: Variable Speed Drives for HVAC Pumps and Cooling Tower Fans[17], is applied to variable speed drives (VSD) which are installed on chilled water pumps, hot water pumps, and cooling tower fans; all other VSD applications require custom analysis by the program administrator. This measure is **not** applicable for:

- Cooling towers, chilled or hot water pumps with any **process load**.
- VSD installation in existing cooling towers with 2-speed motors (current code requires 2-speed motors for cooling towers with motors greater than 7.5 HP).
- VSD installation in new cooling towers with motors greater than 7.5 HP

Savings Algorithm

ΔkWh = BHP /EFFi * Hours * ESF

Where:

- BHP = System Brake Horsepower (Nominal motor HP * Motor load factor)
  - Motors are assumed to have a load factor of 65% for calculating kW if actual values cannot be determined. Custom load factor may be applied if known.
- EFFi = Motor efficiency, installed.
  - Actual motor efficiency shall be used to calculate kW. If not known a default value of 93% shall be used.
- Hours = Default hours are provided for HVAC applications which vary by HVAC application and building type.
  - When available (provided via Energy Management Software or metered), actual hours should be used.
- ESF = Energy savings factor varies by VFD application. Units are kW/HP.
  - Hot Water Pump 0.249
  - Chilled Water Pump 0.081

XMP Comparison

To compare the Illinois TRM VSD savings algorithm to the XMP deemed savings values, the evaluation team used the stated assumptions for BHP (65%), EFFi (93%), and ESF (0.249 for hot water pumps, 0.081 for chilled water pumps. The sole source of variation in the estimates results from the different hours of operation estimates applied to each building

[17] The Illinois TRM does not provide a source for the savings algorithm used in this calculation.

type. For this analysis, we evaluated the lowest, highest, median, mean, and NEEA (3,753) values for hours of operation according to building type (Table 4).

Concerning cooling, the most comparable application from the Illinois TRM is chilled water pumps. The building type with the lowest estimate for cooling hours of operation is warehouses, which produce a kWh/HP savings value of 44, only 11% of the XMP estimate. The building type with the highest estimate for cooling hours of operation is multi-family high-rises, which produce a kWh/HP savings value of 386, 93% of the XMP estimate. When using the hours of operation estimate provided in the XMP (3,753), the savings value of 212 kWh/HP represents 51% of the XMP estimate.

While the cooling values attained from the comparison to the Illinois TRM are consistently lower than those in the XMP, the heating values are generally much higher. Concerning heating, the most comparable application from the Illinois TRM is hot water pumps. The building type with the lowest estimate for heating hours of operation is restaurants, which produce a kWh/HP savings value of 605, 166% of the XMP estimate. The building type with the highest estimate for heating hours of operation is healthcare clinics, which produce a kWh/HP savings value of 1,525, 418% of the XMP estimate. When using the hours of operation estimate provided in the XMP (3,753), the savings value of 653 kWh/HP represents 179% of the XMP estimate.

Table 4: XMP Comparison to Illinois TRM

Hours of Operation	Cooling (Chilled Water Pump)		Heating (Hot Water Pump)	
	Hours of operation (facility type)	**kWh/HP (% of XMP)**	**Hours of operation (facility type)**	**kWh/HP (% of XMP)**
Low	770 (Warehouse)	44 (11%)	3,476 (Restaurant)	605 (166%)
High	6,823 (Multi-Family High-Rise)	386 (93%)	8,760 (Healthcare Clinic)	1,525 (418%)
Median	3,209	182 (44%)	4,989	868 (238%)
Mean	3,855	218 (53%)	5,140	895 (245%)
NEEA Hours	3,753	212 51%)	3,753	653 (179%)

Massachusetts TRM

Massachusetts TRM measure 3.82: Variable Frequency Drives, covers the installation of variable speed drives across multiple end use types and building types.

Savings Algorithm

Δ kWh = (HP)**(1/η motor)*(kWh/HP)*

Where:

- HP = Rated horsepower for the impacted motor.
- η motor = Motor efficiency
- kWh/HP = Annual electric energy reduction based on building and equipment type (deemed)

XMP Comparison

To compare the Massachusetts TRM VSD savings algorithm to the XMP deemed savings values, the evaluation team used the Motor efficiency (EFFi) assumption from the Illinois TRM (93%), and the lowest, highest, median, and mean values for kWh/HP according to building type. The kWh/HP values utilized in the Massachusetts TRM were produced in a 2010 study using "eShapes 8760 end-use load data to define an end-use demand profile, fan and pump curves to define the response of the fan and pump to each end-use demand point and finally, motor curves to define how that fan and pump demand translates to the wire load"[18]. The sole source of variation in these estimates thus results from the different kWh/HP values applied to each building type. For this analysis, we evaluated the lowest, highest, median, and mean values for kWh/HP according to building type (Table 5).

Concerning cooling, the most comparable application from the Massachusetts TRM is chilled water pumps. The building type with the lowest estimate for kWh/HP is elementary/high schools, which produce a kWh/HP savings value of 675, 163% of the XMP estimate. The building type with the highest kWh/HP cooling estimate is healthcare, which produce a kWh/HP savings value of 2,610, 629% of the XMP estimate.

While the cooling values attained from the comparison to the Massachusetts TRM are consistently greater than those in the XMP, the heating values are even greater. Concerning heating, the most comparable applications from the Massachusetts TRM are hot water pumps, and boiler feed water pumps. These end uses provide similar comparisons, as the building type with the lowest kWh/HP estimate for both hot water pumps and boiler feed water pumps is grocery stores, which produce kWh/HP savings values of 1,808 and 1,777, 436% & 487% of the XMP respective estimates. The building type with the highest kWh/HP estimate for both heating measures is healthcare, which produce kWh/HP savings values of 2,587 and 2,526, 623% and 692% of the respective XMP estimates.

Table 5: XMP Comparison to Massachusetts TRM

kWh/HP Estimate	Cooling (Chilled Water Pump)		Heating (Hot Water Pump)		Heating (Boiler Feed Water Pump)	
	Facility type	**kWh/HP (% of XMP)**	**Facility type**	**kWh/HP (% of XMP)**	**Facility type**	**kWh/HP (% of XMP)**
Low	Elementary/ High School	675 (163%)	Grocery	1,808 (436%)	Grocery	1,777 (487%)
High	Healthcare	2,610 (629%)	Healthcare	2,587 (623%)	Healthcare	2,526 (692%)
Median	-	1,403 (338%)	-	2,223 (536%)	-	2,140 (586%)
Mean	-	1,382 (333%)	-	2,265 (546%)	-	2,213 (606%)

18 Chan, Tumin (2010). Formulation of a Prescriptive Incentive for the VFD and Motors & VFD impact tables at NSTAR.

Indiana TRM

Indiana TRM - Variable Frequency Drives for HVAC Applications[19], applies to variable frequency drives installed on an HVAC system pumps or fan motors. The TRM provides deemed savings values for a variety of measures (VFD CHW Pump, VFD HW Pump, CFD CW Pump), systems (CV reheat no econ, CV reheat econ, VAV reheat econ), and for 5 geographic locations within the state.

Savings Algorithm

ΔkWh *= hp * SFkWh*

Where:

hp = nameplate hp of motor controlled by VFD

SFkWh = kWh savings *factor for the installation of VFD [kWh/hp]*

XMP Comparison

To compare the Indiana TRM VSD savings algorithm to the XMP deemed savings values, the evaluation team made direct comparisons between the XMP and the deemed savings values of each building and measure type specified in the TRM. For this analysis, we evaluated the "CV reheat no econ values" at one location (Indianapolis), for all three building types (Large Office, Hospital, Hotel).

Concerning cooling, the most comparable application from the Indiana TRM is the VFD CHW chilled water) pump. The building type with the lowest estimate for kWh/HP is large offices, which produce a kWh/HP savings value of 3,865, 931% of the XMP estimate. The building type with the highest kWh/HP estimate is hotels, which produce a kWh/HP savings value of 6,657, 1694% of the XMP estimate.

The Indiana TRM is the only evaluated TRM which has a measure which may be considered comparable to cooling towers (circulating water pump). The building type with the lowest estimate for kWh/HP is hotels, which produce a kWh/HP savings value of 77, only 43% of the XMP estimate. The building type with the highest kWh/HP estimate is hospitals, which produce a kWh/HP savings value of 1,989, 1105% of the XMP estimate.

Concerning heating, the most comparable application from the Indiana TRM is heating water pumps. The building type with the lowest kWh/HP estimate is large offices, which produce a kWh/HP savings value of 3,933, 1078% of the XMP estimate. The building type with the highest kWh/HP is hotels, which produce a kWh/HP savings value of 7,903, 2165% of the XMP estimate.

[19] The Indiana TRM does not provide a source for the kWh/HP values uses in this analysis.

Table 6: XMP Comparison to Indiana TRM

Building Type	Cooling (Chilled Water Pump) **kWh/HP (% of XMP)**	Cooling Tower (Circulating Water Pump) **kWh/HP (% of XMP)**	Heating (Heating Water Pump) **kWh/HP (% of XMP)**
Large Office	3,865 (931%)	951 (528%)	3,933 (1,078%)
Hospital	6,655 (1,604%)	1,989 (1,105%)	6,146 (1,684%)
Hotel	6,657 (1,694%)	77 (43%)	7,903 (2,165%)

Appendix 2: Pump Load Type Classifications

The CBSA included five pre-coded categories for its pump function field as well as a variety of open-ended categories included as "other" responses. Apex classified these pump functions according to their likelihood to serve variable loads, as summarized in Table 7.

Table 3

Table 7: Load Type Classification by Pump Function

Pump Function			Likely variable load (Y/N)
Coded Categories	Condenser Fluid		Y
	Heating Hot Water		Y
	Domestic Hot Water		N
	Chilled Water		Y
	Pressure Boosting		Y
Other Categories	Pool and Spa	Circ pump for pool thru filters	N
		Pool	N
		Spa water circ thru filters	Y
		Pool pump	N
		Pool water filter and heater	N
		HOT TUB WATER PUMP	Y
		Spa	Y
		Pool water	N
		Therapy tub pool	Y
		Pool water circulation	N
		Pool water treatment	N

Pump Function			Likely variable load (Y/N)
		Hydrotherapy	Y
		Hot tub	Y
		Pool Filter/circulation	N
		Pool filter	N
		Spa filter	Y
		Spa jet	Y
	Boiler Feed Water	Feed water for steam boilers	N
		boiler feed	N
		Boiler circ	N
		boiler feedwater	N
		Boiler feed water pump	N
		Boiler feed water	N
		Feedwater	N
		feedwater for autoclave steam boiler	N
		Feedwater tank circulation	N
		Boiler equipment pump	N
		Boiler feed pumps	N
	Boiler Condensate	Boiler condensate vacuum pump	N
		Condensate Transfer	N
		Condensing Pumps	N
		Condensate receiver	N
		Condensate return	N
		Recirculation of the condensate return tank	N
	Heating & DHW Circulation	Circulation pump	Y
		Recirculation- space heating and dhw	Y
		Heating recirc	Y
		Heating and Cooling Circulation	Y
		DUAL TEMP CIRCULATOR	Y

Pump Function			Likely variable load (Y/N)
		Radiant Floor	N
		Heating hw and dhw	Y
	Geothermal	Well pump for geothermal	N
		Heat recovery loop	N
		Ground loop	N
		Geothermal	N
	Snow Melt	Snow melt	N
		Snowmelt	N
		Snowmelt	N
		Radiant snow melt	N
		Snow melt boiler pump	N
		Primary boiler Pump for snow melt boiler	N
	Domestic Cold Water	Dcw	N
		Domestic cold water	N
		Domestic soft cold water	N
		Building Chilled Water Circulation	Y
		Used for pumping groundwater to well	N
		Domestic water	N
	Fuel Pumps	Fuel tank pump	N
		Fuel oil backup pumps	N
		Fuel pump	N
		Fuel	N
		Diesel fuel for trucks	N
	Water Features	Outdoor fountain	N
		Water featurez	N
		Water feature	N
		Water feature	N
		Dental equipment	N

Pump Function			Likely variable load (Y/N)
	Medical Equipment	Med vac	N
		Medical vacuum	N
		Dialysis equipment	N
	Fire Safety Equipment	Fire Sprinklers	N
		Sprinklers	N
		Fire pump	N
	Other	Process hot water	Y
		surge tank pump	N
		Heat Recovery	N
		Solar lreheat	N
		Soap for the car wash	N
		Boiler pump car wash	N
		Surge Tank	N
		Deaerator Tank	Y
		Sump pump	N
		Wastewater pumps	N
		Vacuum	N
		Glycol charging from storage tank	N
		And filter pump	N
		Accumulator pump to aerator for feed water	N
		Air vacuum pump	N
		Steam	N
		Heating and Cooling	Y