Seeing Is Believing:
Data Visualization Dashboard Turns Ski Area Staff into Efficiency Experts

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ABSTRACT

Snowmaking is often the single most energy-intensive factor in a ski area's operation. Factors contributing to production costs are highly variable, and typically relate to equipment being used, current energy pricing, and ever-changing weather conditions. Quantifying these factors' influence on monthly utility costs has, until now, been a largely unmet task— leaving operators to rely on educated guesswork to efficiently manage snowmaking.

In 2016, an energy efficiency utility in New England changed the game by creating a web-based visualization dashboard that not only provides real-time financial effects of operational changes and equipment upgrades, but also predicts the future of snowmaking.

The utility integrated predictive modeling into an energy management information system (EMIS) dashboard, allowing mountain operations staff to compare current production costs to those that are typical under similar conditions. This dashboard provides mountain staff with real-time feedback on the financial effects of any changes in operations, energy prices, and equipment. It also normalizes for weather conditions. With the dashboard, staff can forecast costs several days in advance, to predict the price of snow production.

The efficiency utility dispatched technical assistance and the dashboard to each of six ski areas, offering real-time data, and considering critical variables to inform snowmaking staff of the financial impact of their decisions. This case study of the snowmaking dashboard compares baseline, pre-dashboard snowmaking efficiency, to post-dashboard efficiency; and offers lessons learned on what it takes to go from an idea that fills a gap to implementing the solution and critically evaluating its economic and environmental effects.

Introduction

In 2016, the Vermont Energy Investment Corporation (VEIC), the administrator of Efficiency Vermont (an energy efficiency utility), provided snowmaking dashboards to six ski areas, each of which had different operational profiles. Each ski area received true-power and fuel metering information for all loads related to snow production, two wall-mounted tablets for viewing the dashboard, and training in its capabilities and functionality.

The web interface consolidates all captured data in terms of dollars per acre-foot, a universal metric familiar to all ski areas' mountain staff. Kilowatt-hours is a less well-understood metric, but nearly everyone can quickly comprehend the value and scalability of a dollar metric.

The real-time performance feedback is shown on a tablet's screen directly over the modeled performance that the ski area typically achieves under the same conditions. The model follows International Performance Measurement and Verification Protocol (IPMVP) Option C to calculate whole-system savings. Comparing intuitive performance metrics from real-time data to those predicted by the model allows for quick and accurate assessment of operations efficiency. Historically, this approach involved a complicated process, and was seldom used.

What the Dashboard Shows: Comparisons and Differences

The dashboard contains a summary and a graph that shows operational efficiency across units of time, ranging from one hour to the season to date. When real-time operations are more efficient than predicted, the cost box is color-coded green, as shown in Figure 1.

Figure 1. Efficiency Vermont's snowmaking dashboard, displaying efficient operations across one week.

When operations are less efficient than typical, the box is red, as Figure 2 illustrates. The color coding allows mountain staff to quickly assess the current state of efficiency without having to use their own arithmetic.

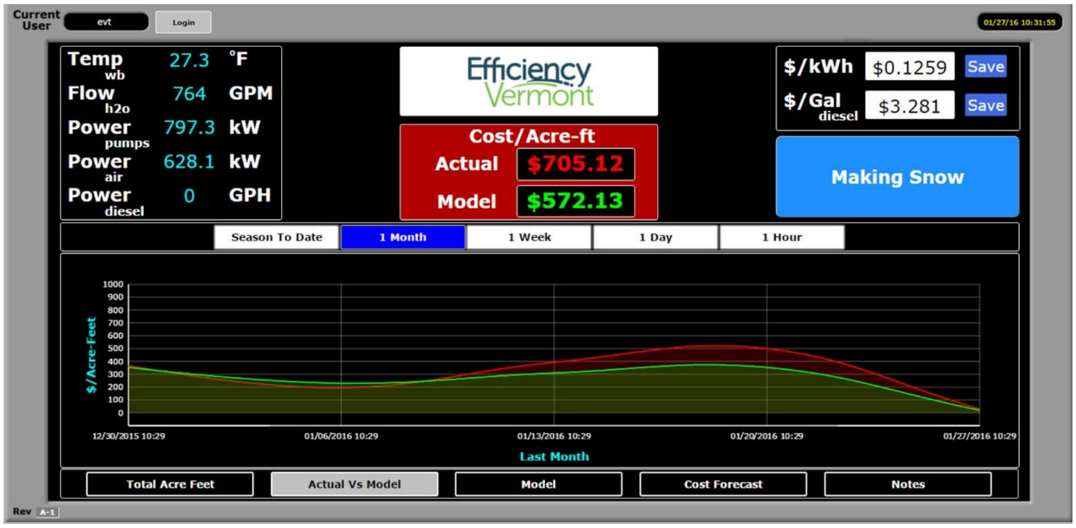


Figure 2. VEIC snowmaking dashboard, displaying inefficient operations across one month.

The dashboard also displays the history of modeled vs. actual costs in a scalable, time-series graph. This visualization allows staff to investigate trends of efficiency, determine the cause, and reproduce or rectify those actions, as appropriate. Thus, staff can easily compare shifts, time units, and / or equipment use, and consider weather factors that influence efficiency.

Forecasting

Although long-term budgeting for weather-driven production costs is a persistent challenge for ski areas, Efficiency Vermont recognized a benefit from it. Short-term weather forecasts for ski areas can be fairly reliable, and so the dashboard design used these forecasts to predict the energy costs of snow production, days in advance. In a similar way, energy prices in New England fluctuate, even down to the hour. So the dashboard integrates energy pricing and weather factors, giving ski areas the ability to forecast snow production costs well before it needs to produce snow. Forecasting allows ski areas to plan for and capitalize on times when snow production is cheapest. The dashboard's energy forecasting functions are illustrated in Figure 3.

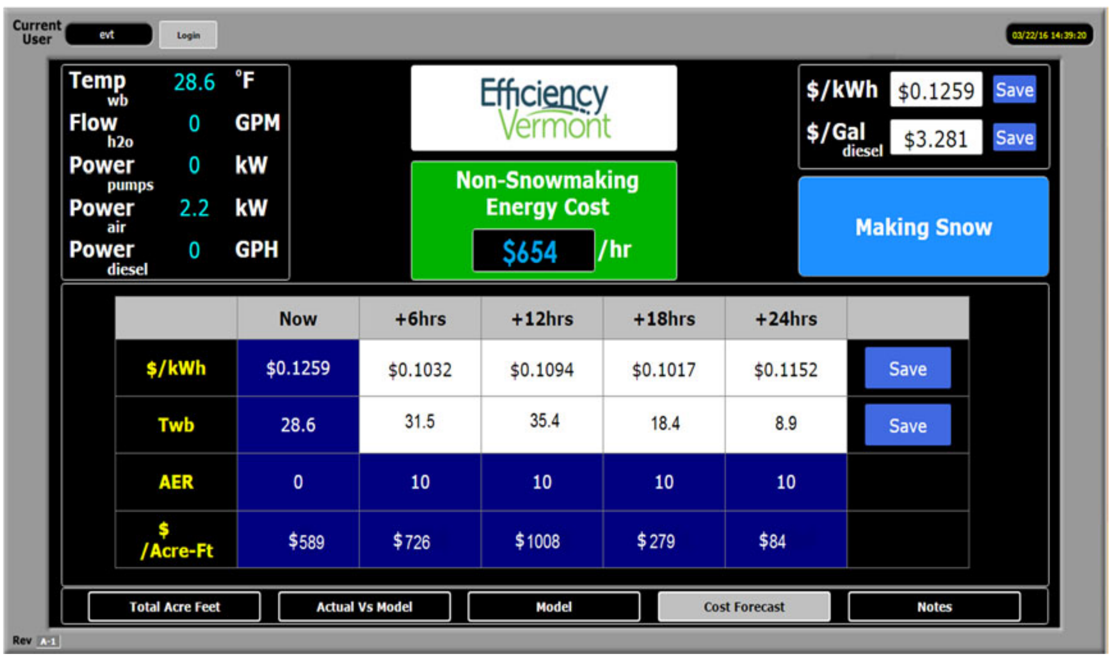


Figure 3. Efficiency Vermont dashboard, displaying snow cost prediction.

The snowmaking dashboard pilot sought to determine if timely, accurate, and consolidated information yielded more efficient snow operations. The dashboard pilot ran from November 2016 through March 2017. Each ski area's operations and management staff received training in the tool's purpose, functions, and capabilities. What were the effects for each area?

Control Participants

An unanticipated control group emerged from this pilot. One participant's infrastructure required postponing the snowmaking dashboard, and another was under the mistaken impression the tool was not operational during the 2017 ski season (November 2016 through April 2017).

The silver lining: the existence of two participants for whom VEIC created reliable statistical models and who were not influenced by the dashboard. Comparing the 2017 season of these two participants to those using the dashboard allowed a check on whether the Experiment Group's results were based on dashboard use, rather than on variables potentially not accounted for.

Control Participant 1

With 2016 ski season data as a baseline, VEIC's statistical model for Control Participant 1 resulted in an R^2 of 77 percent. VEIC plotted baseline efficiencies according to actual electricity use in the 2017 season. Figure 4 shows two seasons of snowmaking operations from Control Participant 1's 2016 baseline season and the 2017 control season.

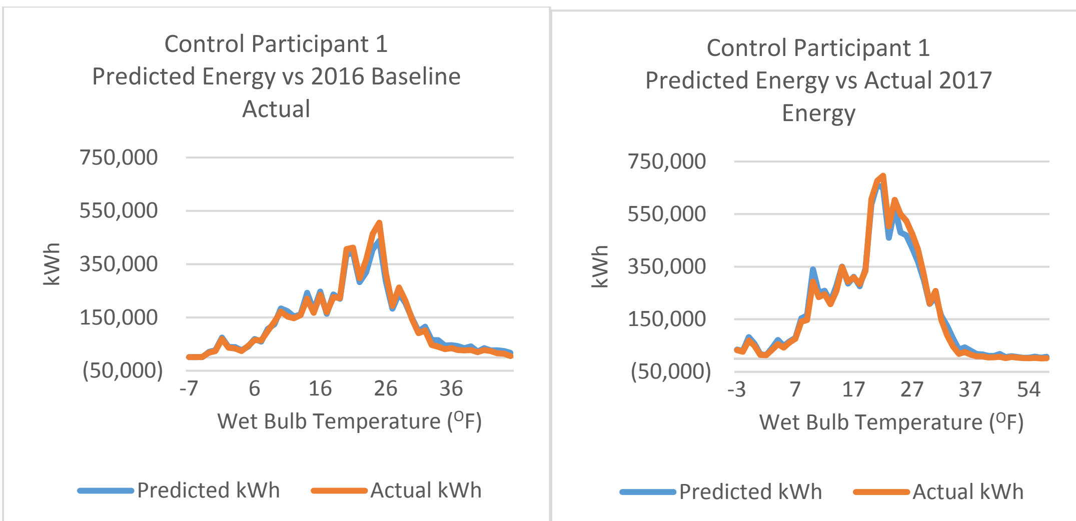


Figure 4. Control Participant 1 baseline actual vs. model and 2017 actual vs. model: no significant change.

Control Participant 1 showed no significant difference between the 2016 baseline year and the 2017 season. Actual use was 26,000 kWh (0.4 percent) more than the model predicted.

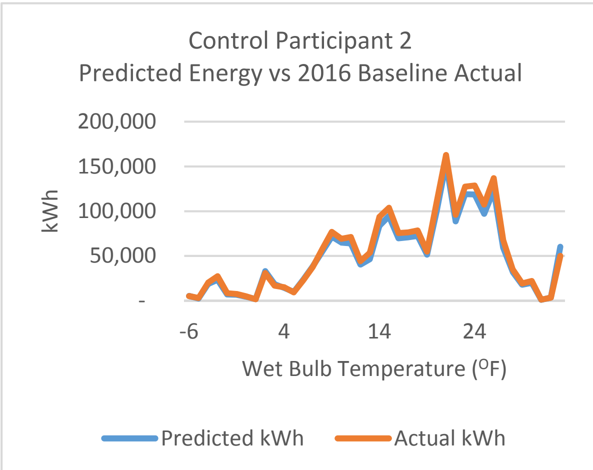
Control Participant 2

VEIC created a similar statistical model for Control Participant 2, resulting in an R^2 of 84 percent, and plotting baseline efficiencies according to actual electricity use in the 2017 season. Figure 5 summarizes two seasons of snowmaking operations from Control Participant 2.

Control Participant 2's data also showed no significant difference between the 2016 baseline year and the 2017 season. In accounting for efficiency measures installed in the 2017 season, actual use was 8,000 kWh (0.4 percent) more than predicted.

Control Results

The difference between the 2016 baseline year and the 2017 season for both Control Group participants accounted for less than 1 percent of total snow production energy used. Thus, the control subjects experienced seasonal variations similar to the experiment group, but energy use remained consistent and predictable.



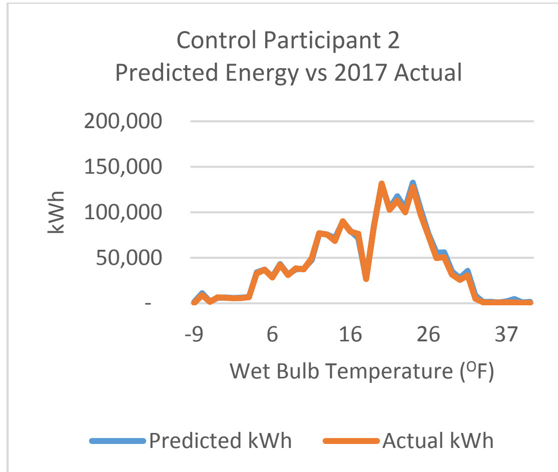


Figure 5. Control Participant 2 baseline actual vs. model, and 2017 actual vs. model indicate no significant change.

Experiment Group

The Experiment Group comprised four small to medium-large ski areas, each of which embraced different energy efficiency innovations, and each of which wanted to optimize its production efficiency via the dashboard. VEIC's statistical models for each resulted in R^2 values ranging from 84 to 97 percent.

Participant 1

Participant 1 is a medium-large ski area that has actively pursued innovative, energy-efficient snowmaking technologies for more than 10 years. Its control systems are sophisticated, allowing users to remotely start and stop large equipment; and view a snapshot of real-time flow, amperage, and operational status of equipment. The baseline model for this ski area was relatively straightforward, offering an excellent statistical model for comparison. Participant 1's model resulted in an impressive R^2 of 97 percent, as shown in Figure 6.

Of the six ski areas, Participant 1 was the most interested in piloting the snowmaking dashboard to further optimize its operations. Their longtime reliance on web operating systems made them able and willing to alter production actions, using information on a computer screen.

Installation

To acquire reliable power data on snow production equipment, Efficiency Vermont began in summer 2015 installing true-power meters on each of the snow production components for Participant 1. Installing sub-metering equipment was the most challenging and time-consuming aspect of providing operational dashboards to Participant 1. Access to communication lines, coordinating the installations during non-snowmaking periods, and commissioning were the three factors limiting dashboard integration, delaying meter data access until November 2016.

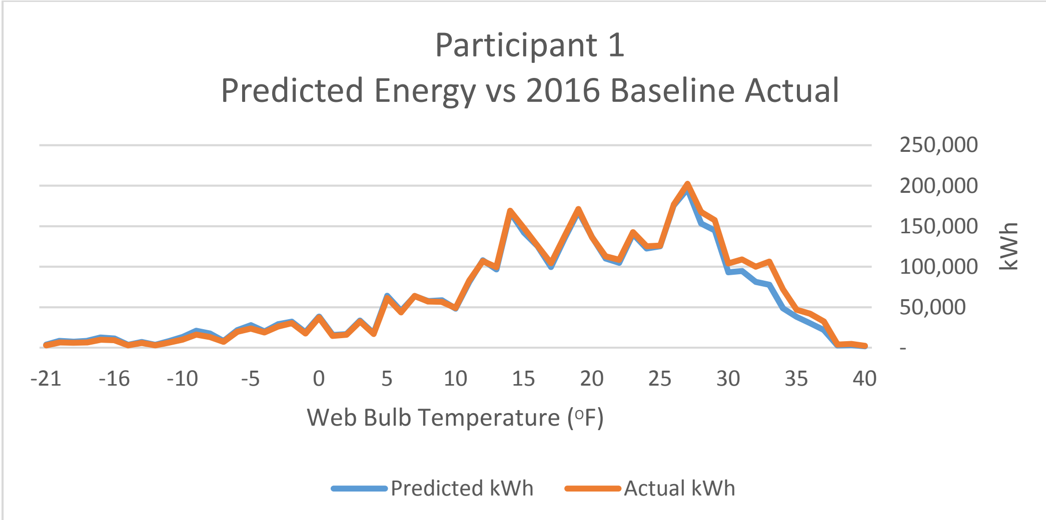


Figure 6. Participant 1's statistical model vs. baseline actual consumption.

Participant 1 Results

Despite the installation challenges, Participant 1 received its dashboard in November 2016. Following an hour-long training and Q&A session for mountain operations and management staff, Participant 1 used the dashboard, and immediately optimized its snow production and efficiency. In late December, Participant 1's president also received training.

Figure 7 compares the snow production efficiency, derived from the baseline season, to the 2017 season's snow production efficiency as it relates to temperature.

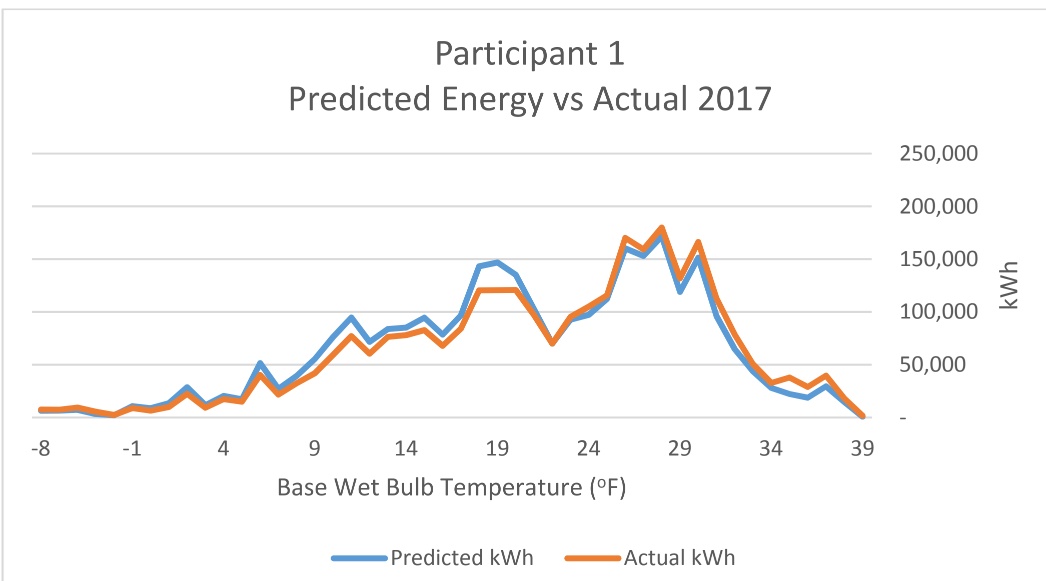


Figure 7. Participant 1's predicted vs. actual energy use in the 2017 season.

For most snow-making temperatures, predicted energy use is greater than the actual use; therefore, these differences represent energy savings that have been normalized for all other significant variables. Figure 8 chronologically compares predicted and actual energy use.

For most of the season, after ski area operations staff were trained to use the dashboard, operations were generally more efficient than those of the prior year. When the president received dashboard training, the efficiency improved further. Thus, it is important for leadership staff to be aware of and engaged in efficiency.

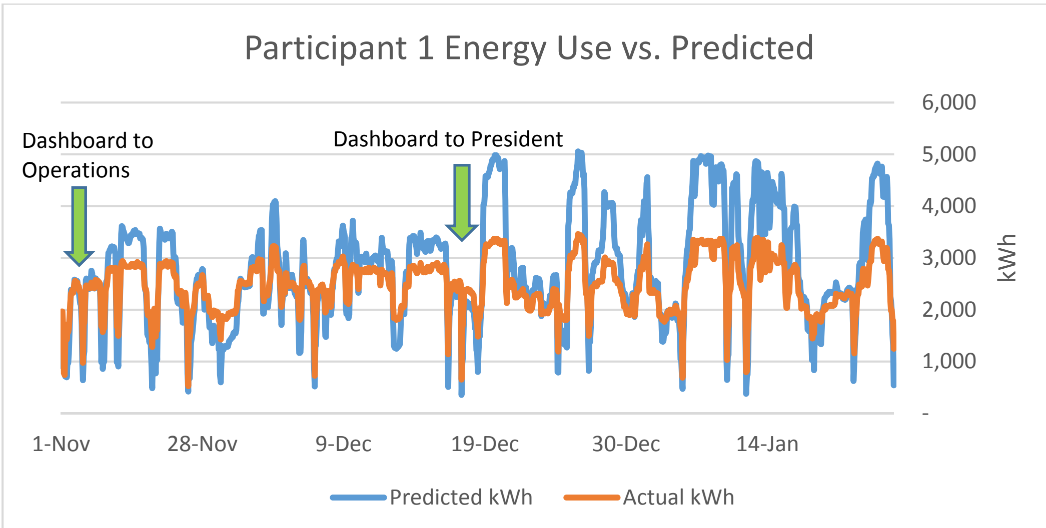


Figure 8. Participant 1's chronological efficiency comparison.

For Participant 1, the cumulative energy savings in the 2017 season reached just over 360,000 kWh (Figure 9), representing approximately 12 percent of total snowmaking production energy, or $54,000 at current energy prices. This finding suggests that the snowmaking dashboard for this participant likely had a positive effect on their snowmaking efficiency.

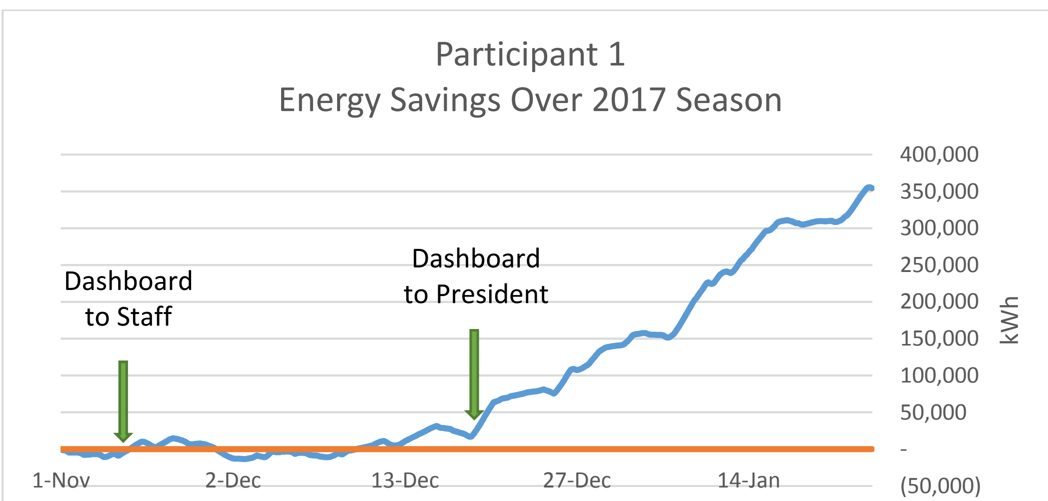


Figure 9. Participant 1's cumulative energy savings during 2017 season

Participant 2

Participant 2 is a medium-small ski area that has also been actively pursuing innovative, energy-efficient snowmaking technologies over the past 10 years. Management has continued making capital investments to increase snowmaking efficiency, however it has not actively monitored its snowmaking operations. Snowmaking facilities are geographically remote from management offices, and operations typically occur at night, when owners are not on site.

Installation

Meter installation for Participant 2 began in summer 2015, and the installation of the sub-metering equipment also delayed delivery of this participant's dashboard. The issues involved the remoteness of the equipment, coordinating the installations during non-snowmaking periods, and installation by electricians unfamiliar with the meters. Live access to the meters occurred in November 2016.

Participant 2 Results

Participant 2 baseline model used 2016 season data, resulting in an R^2 of 91 percent. This model compares the efficiency of Participant 2's snowmaking operation to the 2017 season, and changes immediately upon receipt of the dashboard on December 7, 2016 (Figure 10).

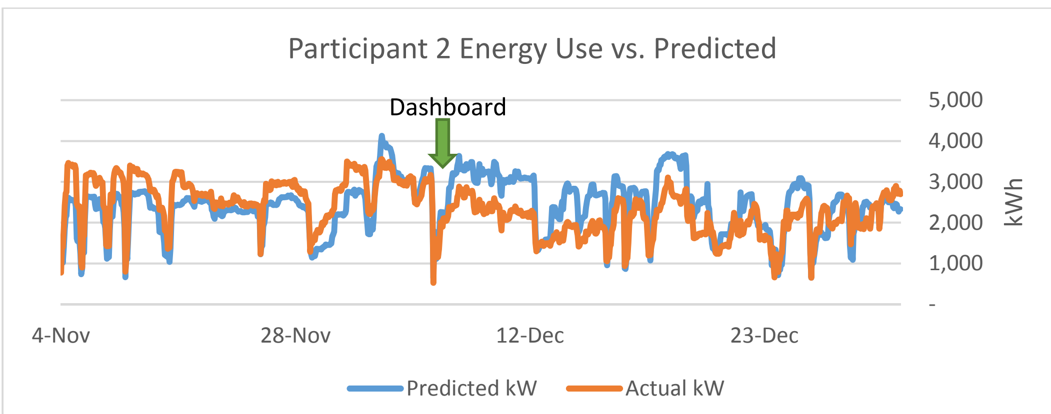


Figure 10. Participant 2's chronological efficiency comparison.

The cumulative sum of savings over the 2017 season shows that early-season snowmaking was less efficient than typical. However, efficiency immediately improved with dashboard use. Figure 11 shows the inefficiencies and savings occurring over the 2017 season through a cumulative sum of savings.

Participant 2's efficiency degraded to a negative 150,000 kWh, compared to the baseline model prior to the dashboard, and then gained 76,000 kWh in savings above baseline efficiency for the season. Factoring in early-season inefficiencies, Participant 2 realized a net gain of over 220,000 kWh from the snowmaking dashboard, or $33,000 at current energy prices.

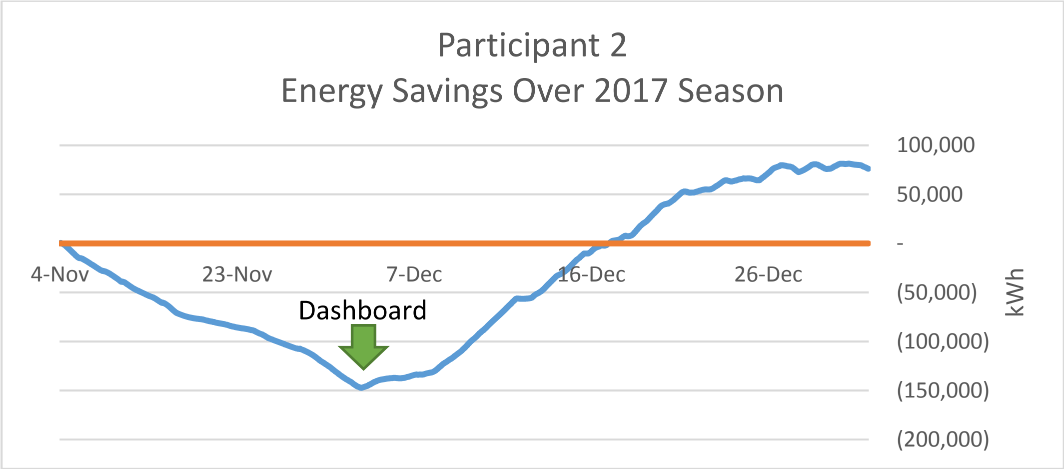


Figure 11. Participant 2's cumulative energy savings during the 2017 season.

Participant 3

Participant 3 is a medium-small ski area that has sought innovative energy-efficient snow production equipment in the past several years, including control systems that allow insights into their snow production process. This participant expressed moderate interest in optimizing their production efficiency by using the dashboard.

Installation

Meter installation for Participant 3 was easier, due to the timing of other improvements at the facility. Participant 3 installed pump upgrades in summer 2015, and Efficiency Vermont helped the onsite contractor install meters on the snowmaking equipment. The contractor knew the meter equipment and efficiently coordinated the installation. In November 2015, Efficiency Vermont had remote access to all snowmaking load data.

Participant 3 Results

Although Efficiency Vermont could access the data earlier than for the other participants, the configuration and operations of the snowmaking system made modeling more difficult. To provide meaningful, real-time feedback, a dashboard must provide an energy metric for active snowmaking. Thus, pumps that intermittently transfer water should not be used in the formula. Operators will see degraded performance each time a transfer pump turns on, absent other operational changes. This would provide conflicting and potentially confusing feedback.

As such, only pumps used for active snowmaking should be used for feedback. However, Participant 3 uses some pumps for transfer *and* for active snowmaking—with no flow meters for determining if the water is being transferred or making snow. The ski area estimated that the most pumping is used for active snowmaking; so Efficiency Vermont's model included the flow and pump power, assuming 100 percent was for active snowmaking. This relationship created a less reliable model, even considering the resulting model R^2 of 84 percent. Staff were aware that each time a pump turns on to transfer water, the dashboard would show a slightly more efficient metric than reality. As more data accrue, the confidence level in this model will likely improve.

Although this model might be less precise, the dashboard's effects remain clear. In early December, Efficiency Vermont introduced and trained Participant 3 on the dashboard, with immediate effects (Figure 12 and Figure 13). In plotting the cumulative sum of energy savings over the 2017 season, it become clearer that early-season snowmaking was less efficient than typical. However, with the dashboard, efficiency immediately improved (Figure 13).

Figure 13 also illustrates the energy savings plateaus within three weeks of using the dashboard. Staff noted that they remained focused on preparing trails for the Christmas holiday and did not monitor the dashboard closely during and after this period. This feedback and resulting findings suggest a good opportunity for a continuous energy improvement (CEI) plan to maintain momentum in optimizing efficiency throughout the season.

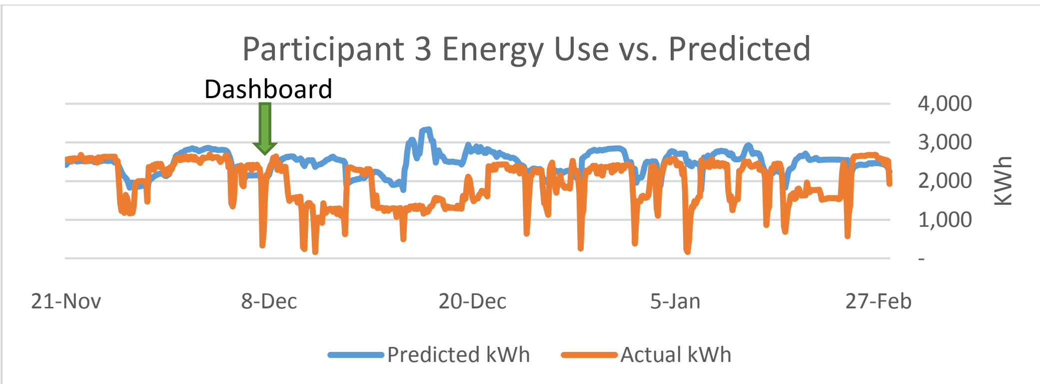


Figure 12. Participant 3's chronological energy use, post-dashboard vs. modeled energy use.

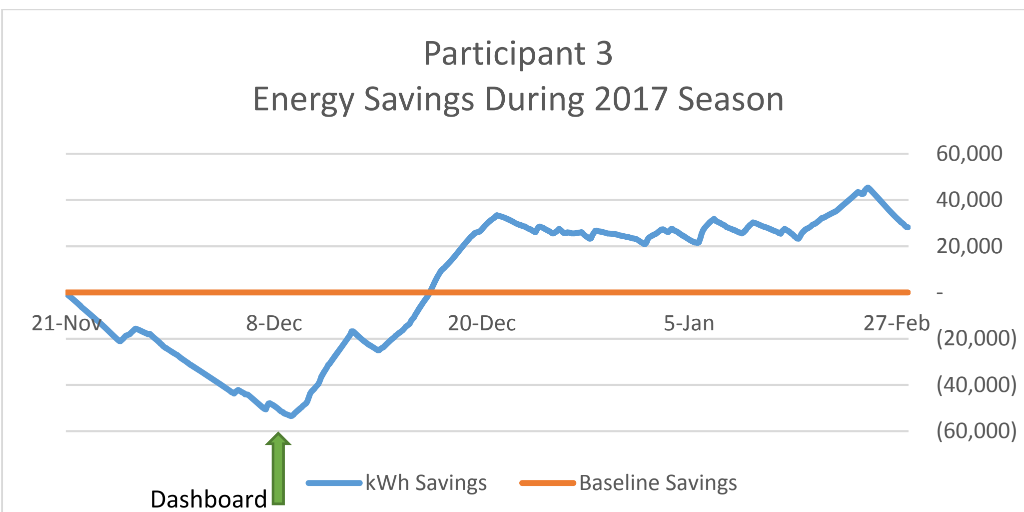


Figure 13. Participant 3 cumulative sum of energy savings during 2017 ski season.

In the context of pre-dashboard efficiency degradation: During dashboard use, Participant 3 saved 82,000 kWh, or $12,000 in the 2017 ski season—7 percent of all snow production costs.

Participant 4

Participant 4 is also a medium-small ski area that has sought innovative energy-efficient snow production equipment in the past five years. It is generally interested in efficiency, and has recently begun investing in more efficient equipment. It also has invested in control systems that allow insight into its snow production process. Participant 4 showed mild interest in optimizing production efficiency via the dashboard, but was not convinced it would help.

Installation

Meter installation was mixed. An onsite electrician familiar with the equipment installed them with no data quality issues. However, because this work was continually de-prioritized on the electrician's regular list of projects, there were significant delays in installing them. Meter data access became available in December 2016. Another complication was Participant 4's intermittent use of diesel compressed-air snowmaking equipment. Participant 4 installed diesel fuel flow meters to quantify diesel use, but no comparison baseline data existed. Diesel accounted for approximately 14 percent of all compressed air energy at this ski area. To compare the pre- and post-dashboard periods, all data using diesel compressors were omitted from the dataset. Participant 4 will use a different model that incorporates diesel for the 2018 season.

Participant 4 Results

Participant 4's baseline snowmaking energy use resulted in a regression model with an R^2 of 84 percent. Participant 4 received dashboard training in early November 2016, and throughout the season, it predominantly operated more efficiently than in the previous year (Figure 14). Participant 4 also saw a steady rise in energy savings that season (Figure 15).

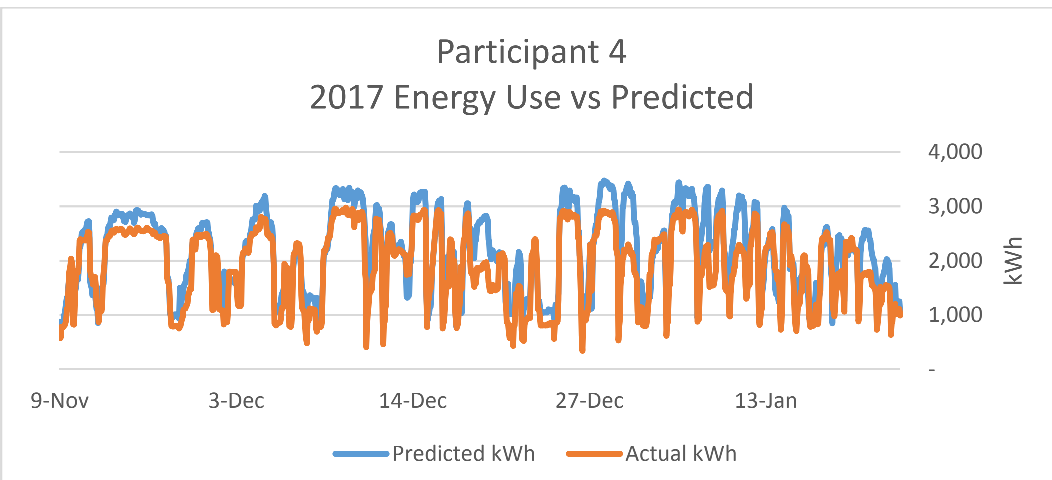


Figure 14. Participant 4's chronological energy use comparison, pre- and post-dashboard.

The cumulative energy savings Participant 4 experienced in the 2017 season reached over 300,000 kWh, representing approximately 12 percent of total snowmaking production energy for this ski area, equating to over $45,000 in cost savings.

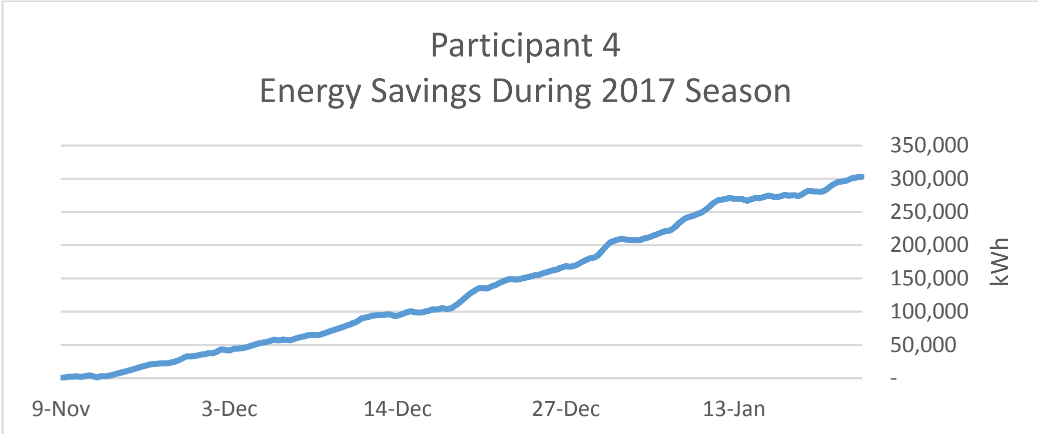


Figure 15. Participant 4's cumulative sum of energy savings over the 2017 season

Summary of the Project and Its Findings

Six ski areas entered a pilot to determine whether an EMIS, tailored to their industry, would influence snowmaking efficiency. Of these 6, 2 served as control subjects, because they did not use an EMIS and experienced predictable energy use through the post-dashboard pilot period. The control subjects experienced a 0.4 percent variance in energy use from what was predicted through regression modeling. The 4 participants in the Experiment Group varied in size, energy consumption, geography, and historical adoption of innovative efficiency. These ski areas ranged from early adopters to late majority (Diffusion of Innovation Theory).

All four ski areas in the Experiment Group saved a significant amount of energy by using the snowmaking dashboard. Energy savings ranged from 7 to 14 percent of total snowmaking energy, with total savings equating to 968,000 kWh for the Experiment Group, or $145,000 annually. The annual savings summary for each participant is summarized in Figure 16.

Ski Area	kWh Savings	% of Snowmaking Energy	Dollar Savings
Participant 1	360,127	12%	$54,019
Participant 2	223,400	10%	$33,510
Participant 3	81,709	7%	$12,256
Participant 4	302,977	14%	$45,447
Control Participant 1	(25,995)	0%	$0
Control Participant 2	(7,853)	0%	$0
Total Experiment Group	**968,213**	**11%**	**$145,232**

Figure 16. Summary of participant effects with the snowmaking dashboard.

Each participant's efficiency, post-dashboard, is shown in Figure 17, with savings as a percent of total snowmaking energy used at each ski area.

All participants also experienced a sharp increase in efficiency immediately after receiving the dashboard, suggesting it was informative and encouraged operational changes to increase snowmaking efficiency. Participants reported that the dashboard helped make operations staff aware of inefficiencies in real time, prompting them to change operations. These changes were generally minor and typically involved changing snow guns, fixing leaks, and balancing compressed-air loads.

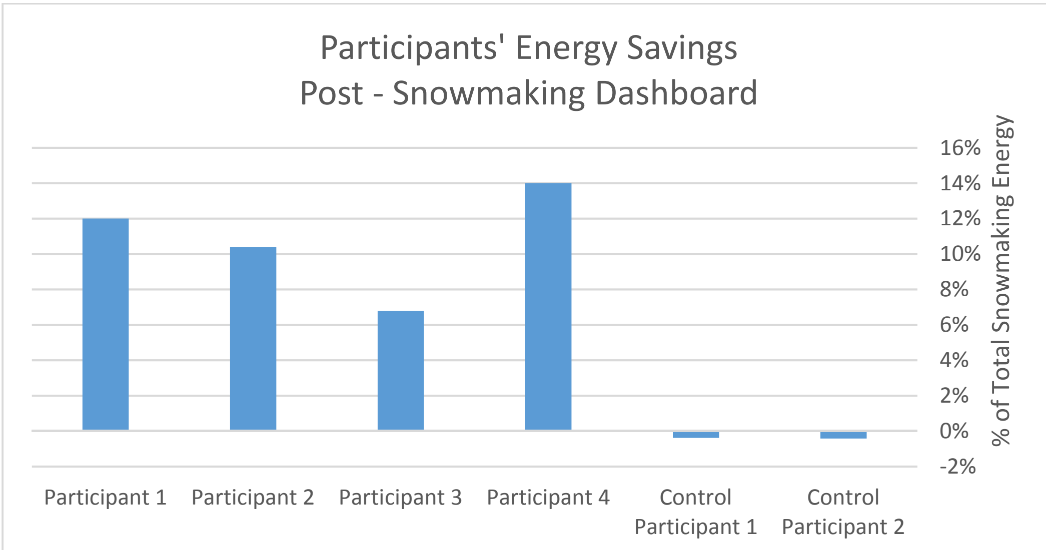


Figure 17. Percent savings of total annual snowmaking energy use, across all participants.

Post-dashboard, two participants experienced immediate energy savings, followed by a plateau of typical snowmaking efficiency several weeks later. The participants reported that they were actively engaged in improving efficiency until the crucial snowmaking period near the Christmas holiday. After this period, they did not monitor the dashboard. The cumulative sum charts for Participants 2 and 3 clearly show the return to baseline efficiency conditions (Figures 11 and 13). These findings suggest an opportunity for a CEI plan, to continue optimizing season-long efficiency for these participants.

This pilot also demonstrated the effectiveness of training a ski area senior executive in dashboard use. Participant 1 experienced savings immediately after training key operations staff, but efficiency doubled after training the president in it (Figure 8). Further, because Participant 1's president was very excited about the tool, staff better understood the influences on costs of snowmaking, which has helped communications between departments.

No clear trends can be seen if early adopter participants achieved different savings from those of late majority participants. The two ski areas that saved the most energy (Participants 1 and 4) were in different innovative adopter categories. It is possible the savings resulted from two different circumstances. Participant 1 actively monitored the system's efficiency and was keen to maintain maximum efficiency; Participant 4 was less engaged, but had more opportunity to improve operations. In any event, the data do not confirm this hypothesis.

Conclusion and Next Steps

In 2016, four ski areas receiving timely, accurate, and intuitive dashboard feedback on their snowmaking operations saved a combined $145,000 by lowering their energy consumption in snow production. Ski areas saving the most energy were the quickest to use the dashboard in their daily operations and continued to optimize their systems throughout the season.

Having collaborated with these ski areas for over 15 years, VEIC and Efficiency Vermont built on a solid base of respect, trust, and engagement, which allowed this pilot to take place. Lessons learned will greatly benefit the next round of snowmaking dashboard participants. All Experiment Group participants expressed a high degree of satisfaction with the dashboard. One said the dashboard was "a groundbreaking development and the future of snowmaking." After the 2017 ski season, most of the remaining Vermont ski areas have requested the dashboard to improve their operations. After a successful pilot, VEIC plans to market the snowmaking dashboard to the rest of the industry in 2018.

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