EMIS Digital Transformation to Empower People

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ABSTRACT

CN Rail Energy Monitoring Information Systems (EMIS) have hundreds of metering points that monitor more than 20 major sites and generate a tremendous amount of data. This deluge of information is a challenge for CN's Energy Management Team of two to organize and share with CN's large user base in a timely and value-added manner. A web-based energy dashboard was implemented at each major site to provide energy data insights that are easy to access and interpret. The development cycle was staff focused through an iterative feedback process to better tailor the information to their needs. Using CN as a case study, this paper shares the people-focused dashboard design process, the results of dashboard driven energy waste investigations, and successes in technology adoptions by staff.

Introduction

CN Rail is a North American transportation and logistics company with a 31,540 km network of rail, and 24,000+ employees that span Canada and U.S. A large EMIS system that monitors multiple facilities at major sites was deployed over the course of several years. With hundreds of metering points that generate a tremendous amount of data, converting this dataset into useful and meaningful insights for CN's staff to effectively utilize is a challenge. The legacy PC-based EMIS software package solution had limited adoption by staff mainly due to complexity with accessibility. The energy management team started a digital transformation of this legacy PC-based EMIS tool to modern, easy-to-access, web-based dashboards using a feedback-based approach, focusing on end users. This has improved access to insights about energy and equipment health and empowered staff to independently detect and investigate potential energy waste incidents.

Hurdles to Universal EMIS Utilization

One of CN's strategic energy management program objectives is to monitor energy consumption in its top consuming sites. An EMIS system monitors twenty-one major yards in North America, with a total monitored electrical load of 30 MW. The monitored load types, shown in Table 1, are monitored using 267 advanced electrical meters that are also configured to capture multiple non-electrical variables such as air flow, pressure, gas consumption, outside air temperature and wind. The central server communicates with these individual meters in real time and the data is processed and stored. On a given day, CN records more than 400,000 new data points from all the connected sources. With such a tremendous amount of data generated, it becomes increasingly complex to convert it into meaningful information that can be used to drive behaviour.

Table 1. Types of loads monitored by CN'S EMIS system

Unique to CN (Railroads)	Standard
Train car repair shops	Office buildings
Locomotive repair centers	Data centers
Switch point snow blowers and melters	Crew break/lunch buildings
Yard control towers	Air compressors

With large datasets that span multiple sites, data accessibility and insights are important. CN's staff of more than 24,000 employees are located across the railway network. The Facilities Management (FM) team of regional supervisors and field staff is responsible for maintaining more than 2,600 buildings and a vast amount of equipment that support the business. Key data insights on equipment and building performance is valuable information for both the maintenance staff and business owners. The CN Energy Management team uses the EMIS system to aid the FM staff to monitor energy consumption as well as track building/equipment performance. With the legacy system, viewing the information was a hurdle for FM staff. The pre-made HMI screens for each site (Figure 1) could only be accessed using a special software package, which the user had to request to be installed on their workstation.

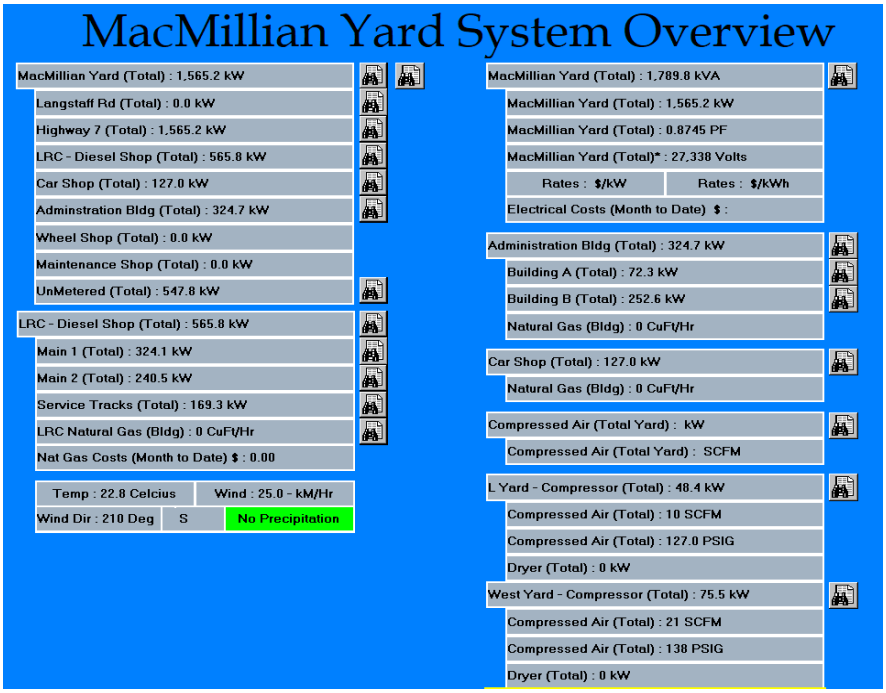

Figure 1 Example of a typical HMI Screen captured from the legacy PC-Based EMIS tool

The staff also needed to be trained to navigate/access the relevant real-time and historical log screens. Historical data analysis also required a multi-stepped method to display and the software package lacked the tools to provide useful data insights such as targets and KPIs (figure 2). As a result of these challenges, the majority of FM staff did not effectively utilize the PC-Based EMIS software package to monitor their buildings and drive energy conservation.

Figure 2 Legacy trend view for a typical compressor

Due the limitations of the PC based tool's historical data analysis capabilities, CN utilized an external cloud-based solution that was used to analyze the historical data gathered by the central EMIS software (Figure 3). The solution provided advanced historical data insights, such as comparisons and a baseline-based tracking package. The historical insights also contained results of energy modelling using linear regression and CUSUM visuals. Although a powerful analysis tool for the Energy Management team, this cloud-based solution was underutilized by the FM staff due to the overwhelming amount of data displayed. Moreover, the lack of real-time data on this platform was an obstacle for adoption by the FM team as they still had to access the PC-based software package to view key real-time indicators regarding their equipment health and performance.

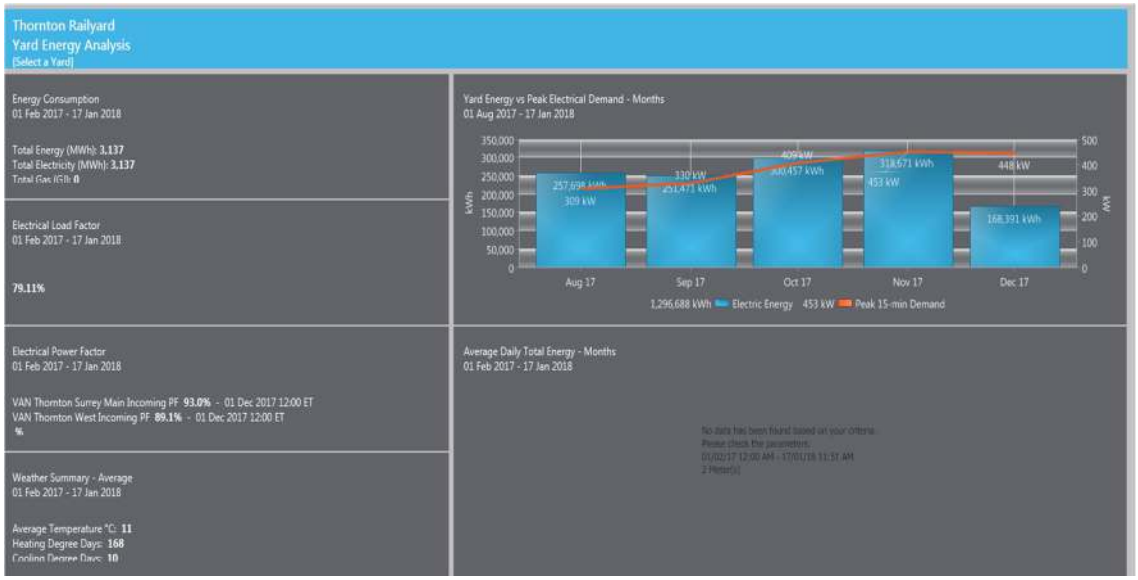

Figure 3 the legacy cloud-based solution for historical data analysis showing a summary page of a yard

The tremendous amount of data available in real-time, as well as the six years of historical logs were underutilized by the FM staff. The limited accessibility and bulkiness of the PC-based EMIS software package was a hurdle for CN's staff to effectively utilize the insights. A web-based EMIS tool that could be real-time easy to use and universal was needed to empower CN's staff to detect energy waste and raise energy conservation awareness.

Feedback-Based Digital Transformation

Based on the issues and lessons learned from the previous EMIS, the CN Energy Management Team developed a plan to deliver against the following four objectives:

- Increase accessibility of EMIS data using a universal web-based tool that can be directly accessed from any CN workstation by all CN employees.
- Develop a common dashboard portal that can display real-time data, as well as historical trends to reduce the number of software packages that must be learned and adopted.
- Tailor the universal dashboard portal by site and region to better organize the data, while ensuring that users have access to any site if needed.
- Develop a centralized, real-time alarm engine to better inform CN FM staff of any changes in energy consumption or abnormalities in equipment performance.

The first step towards a digital transformation was to assess the current EMIS technology and assess gaps in meeting the above requirements. The legacy EMIS resided in an obsolete server that was no longer supported and increasingly difficult to maintain performance for a smooth user experience. The EMIS's web capabilities lacked native HTML5 support and could not dynamically display historical data in a dashboard style. Based on this assessment, it was clear that the EMIS technology needed to be upgraded to a version with more functionality; notably the capability to display real-time data as well as historical time-series charts. Using a multi-step approach, the windows server environment and SQL database were upgraded, followed by a software migration to Schneider Electric's Power Monitoring Expert 8.2. This new web-based dashboard was named Energy Management eXcellence (EMX).

Using the new EMIS software features, the Energy Management Team created a template dashboard for a large yard based on lessons learned from the old system, the cloud-based historical analysis tool and the energy information handbook. Feedback sessions were held with facility managers, equipment owners and energy consultants. The feedback was carefully reviewed against the capabilities of the web-based software engine powering the dashboards. The test dashboard was then deployed for hands-on testing by the FM team for a final round of feedback. Table 2 shows the three iterations building towards the final EMX dashboard.

Table 2 List of EMX dashboard development iterations, features and steps

Step Id	Key Features Additions
EMX V1	• Real-time data tags for site-level electrical parameters such as power and voltage • Historical data trends for energy and demand

	• Year over year monthly energy consumption comparison
EMX V2	• Dedicated dashboard for each equipment type • Real-time gauges for compressor pressure and flow • Energy usage intensity (EUI) (kWh/ft2) for all buildings and repair shops
EMX V3	• Energy modelling dashboard for sites that could be modelled against weather or production data with a CUSUM value representing savings. • Four-day energy forecasting results based on predicted production and weather data • Real-time single line diagram showing power, power factor and energy/day. • Benchmarking of monitored buildings based on their and data obtained from building performance database (filtered by ASHRAE climate Zones)

As part of the third iteration, the dashboard template was then replicated across twenty other major sites throughout the United States and Canada. The end-users provided key feedback to the Energy Management Team to help improve the browsing experience. Several feedback sessions helped better tailor the dashboards to the needs of the different sites and "personalized" each dashboard collection. This step was crucial to reduce visual clutter from irrelevant data in the original template. A customized dashboard for a typical large yard is shown below in Figure 4.

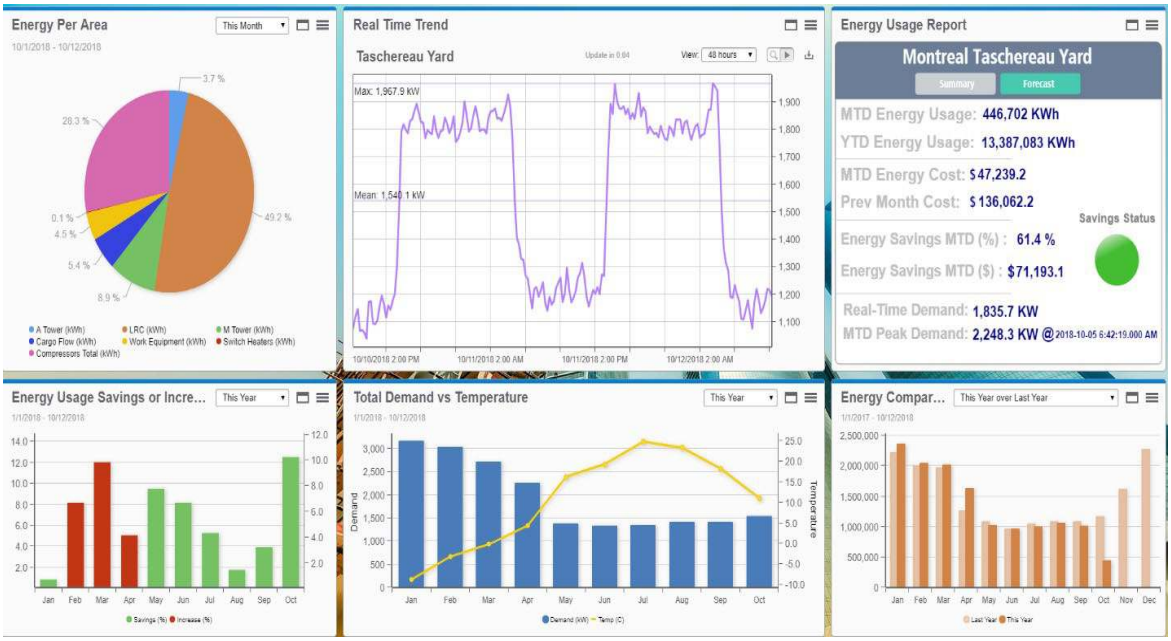

Figure 4 New main EMX dashboard for a typical large yard after the third iteration of feedback.

The main dashboard's goal is to act as a landing page for a particular site, highlighting key information that can be easily modified by the user if needed. The main components include:

- Energy consumption breakdown by sub metered building/equipment;

- A real-time demand graph providing feedback on abnormalities in consumption during typical day-night cycles;
- A comparison of current monthly consumption to that of last year;
- Estimated energy savings based on the weather/production corrected energy modelling results; and
- Monthly energy costs based on the latest rate schedules for the particular site.

To avoid cluttering the user's view, each category of loads has a separate set of sub-dashboards. These sub-dashboards use a combination of real-time data and historical time series charts to aid the user in understanding the performance of their equipment. The compressed air system at CN's yard, for example, is crucial to train operations and FM staff have to actively monitor the system to ensure it functions correctly. Moreover, the compressed air system is a large energy consumer and detecting leaks and abnormally high usage will ultimately help CN achieve energy savings. Figure 5, below, shows ten-second real-time gauges of air flow and pressure, complemented by a configurable historical trend of the compressed air variables, as well as 15-minute electrical demand.

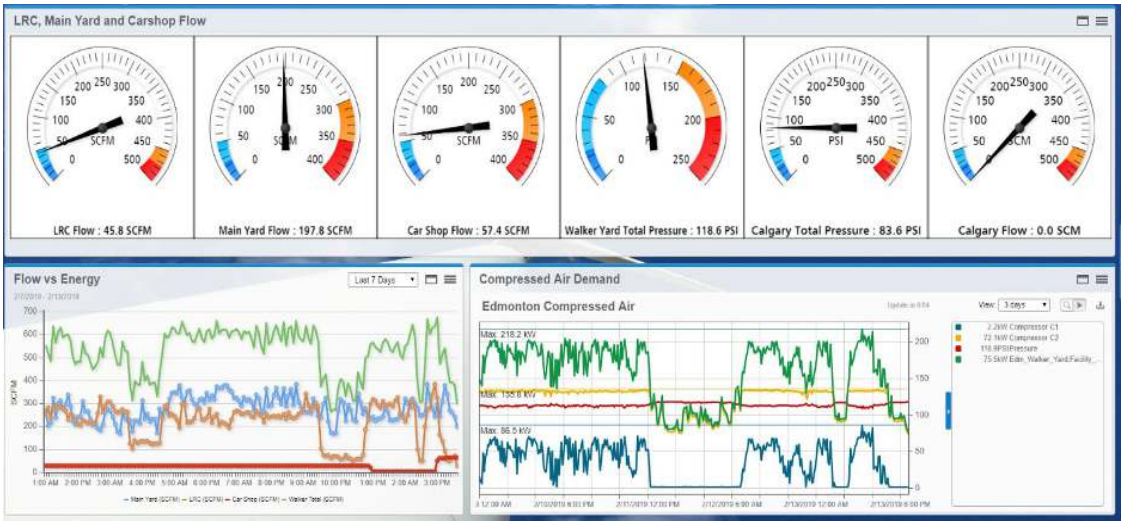

Figure 5 Compressed air monitoring example show flow, pressure, energy and demand in real-time.

To supplement the data visualization, the Energy Management Team launched a dynamic event notification system to notify the user of changes in performance or unexpected high usage. These alarms aim to improve the response time for field incidents. Once an email alert is received, staff can analyze a particular incident using the dashboards and take further action if needed. A monthly Major Incidents Report is compiled by the Energy Management Team and shared with FM staff to document and track changes. Event notification and incident tracking plays a key role in ensuring that equipment performance and health are actively monitored; ultimately reducing energy waste.

The new dashboard design, coupled with meaningful real-time alarms is empowering CN's staff to act upon insights as soon as they occur. By combining easy-to-read equipment visualizations, such as gauges, with configurable energy consumption and demand charts, the staff can now independently find and investigate incidents. The Energy Management Team does not have the resources to monitor potential energy waste incidents on a daily basis. Providing

FM staff with this independence is powerful; FM staff have extensive knowledge of their local assets and can quickly take action to investigate.

Results

The energy dashboards have been a key driver in enhancing energy awareness at CN. The success of the web-based dashboard was initially driven by the need for field staff to access key operational data about their equipment. Combining operationally important data with the energy impact of such equipment has resulted, in many cases, in a positive impact on CN's energy usage. The results, described below, are just a few examples of how CN's staff are being empowered by the dashboard to make a difference.

Enhancing energy visibility and insight accessibility

After piloting the dashboards at one site, the Energy Management Team shared the dashboards with the rest of the FM divisions at CN. After a short adoption period, CN saw a threefold increase in user traffic to its dashboards, when compared to the old PC-based software tool. The Energy Management Team believes this increase is attributed to the fact that the web-based dashboards do not need specific software and can be easily shared using a hyperlink. Moreover, the Energy Management Team helped the regional supervisors setup dedicated screens in their office areas, which helped further awareness about the tool.

With accessible data, facility staff started using the historical and real-time indicators as an issue-tracking tool. In one case, staff used the compressor dashboard to observe its performance and behaviour. With the aid of the real-time gauges, they analyzed the compressed air flow and electrical demand over a 24-hour period. They realized that the compressed air system was only needed for the day shift at one of CN's car repair shops instead of the full 24-hour period that it was left running. Further analyzing the data, the compressor used was a less efficient model and undersized for the compressed air demand needed. The compressor was replaced with a timer-controlled efficient compressor. Once the ECM was implemented, the FM staff monitored the behaviour of the compressor and verified its expected performance, as shown below (Figure 6). This EMIS-driven observation led to a twenty-eight percent reduction in energy consumption. This particular site consumed significantly more energy in 2018 vs 2017. Using the dashboards to make observations, CN staff were able to stabilize consumption and pinpoint areas that needed further investigation.

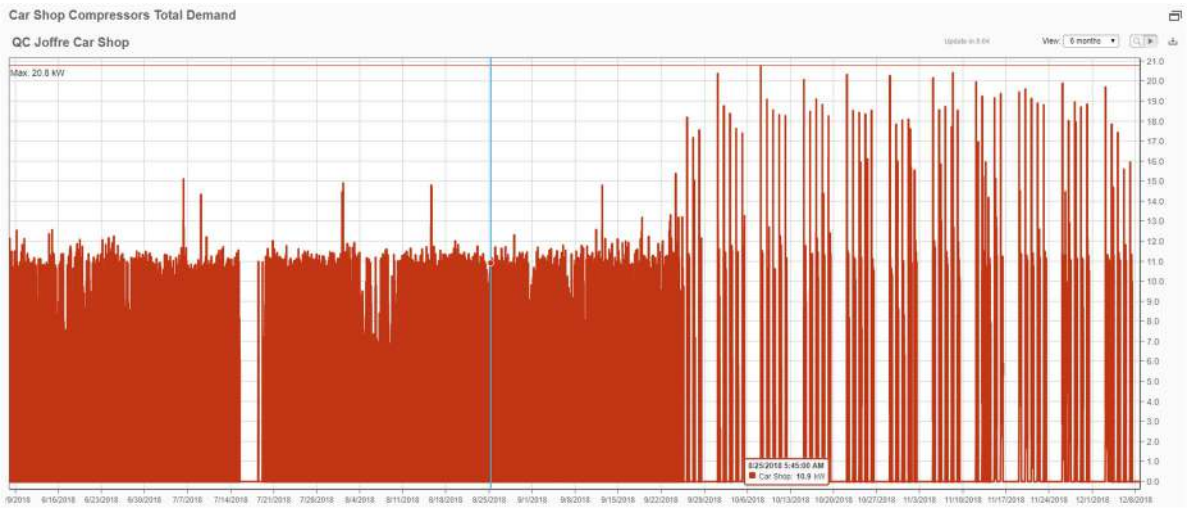

Figure 6 Compressed Air low-cost ECM results driven by EMIS insights. The figure shows the daily demand profile change.

The new EMIS monitors the largest sixty energy consuming buildings of CN's 2,500 buildings, creating a new opportunity for the FM Team to compare buildings with similar usage. By creating an internal benchmark for Energy Usability intensity (EUI), the team can use the EMIS dashboards to detect abnormal energy use behaviours. The example shown in Figure 7 profiles the weekly electrical demand of two office buildings of similar size and type, located at the same site. The day cycles of both buildings have a similar pattern but there is an average 40 kW difference during the night cycle. Based on this finding, the FM Team plans to examine the building automation system's nighttime fallback schedule and the source of the night loads. Access to insights such as this example give facility owners and occupants the ability to find energy waste opportunities that are not covered during regular preventative maintenance cycles.

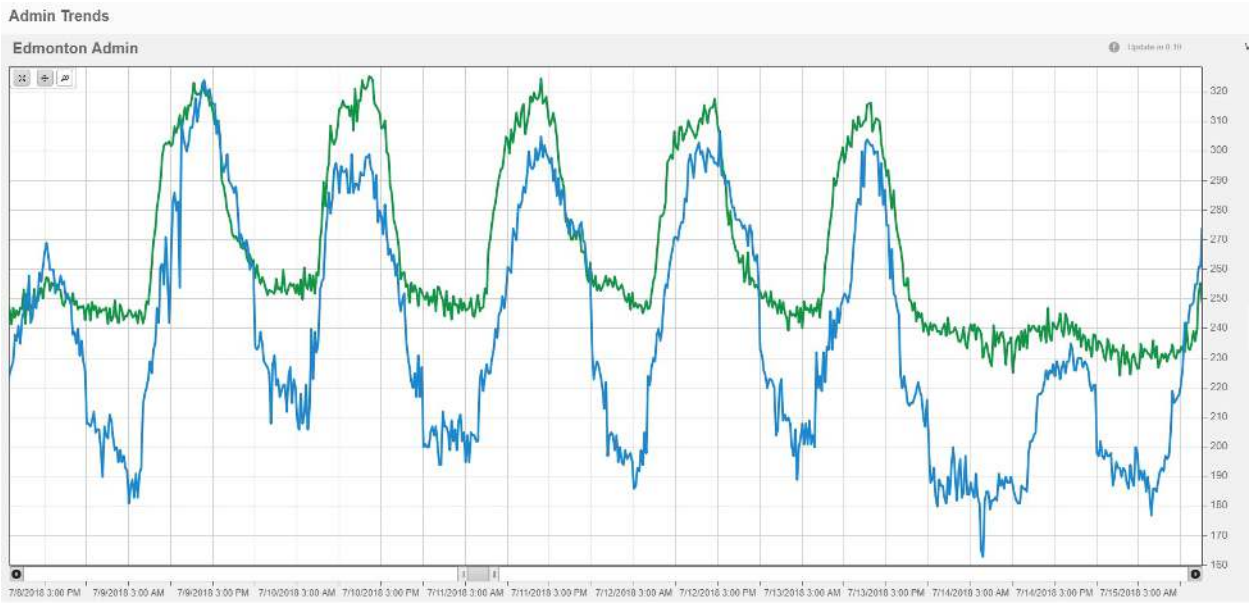

Figure 7 Office buildings of similar size and type located at the same site.

Improved response time

Compressed air systems are dynamic in nature and active monitoring using EMIS data allows employees to understand insights that can be otherwise hard to find. In one instance, two compressors feeding the same air system in the yard experienced an increase in total energy consumption by fifteen percent. Using the web-based gauges, the Energy Management Team noticed that the pressure of one of the supply lines was well below the expected level (Figure 8). There was no indication, however, that something was wrong as the other compressor was running and meeting the end-use air load. The team analyzed the historical average pressure of the line and verified that the drop was unexpected. Using the real-time data input for airflow and demand, the team determined that the main compressor was running but producing much less compressors air. The demand profile trend line clearly indicated that the backup compressor (yellow) was cycling non-stop to maintain supply to the end-user, while the main compressor (blue) was constantly running during the incident period. The local FM staff investigated the incident and discovered that the supply line valve from the main compressor was closed and quickly acted to open it. In post-incident period, the backup compressor is turned on only when end-user peak air demand is reached. Without the EMIS insight, the FM team would not have been notified until the end-use load was not met; which would have caused a delay in train operation if the backup compressor experienced an overload. As a result of this incident, the local FM staff understand the benefits of the EMIS and utilize the dashboards and email alerts to actively monitor the compressed air system's health and performance. An important lesson learned from this experience is that a real, hands-on incident led to successful adoption by local staff.

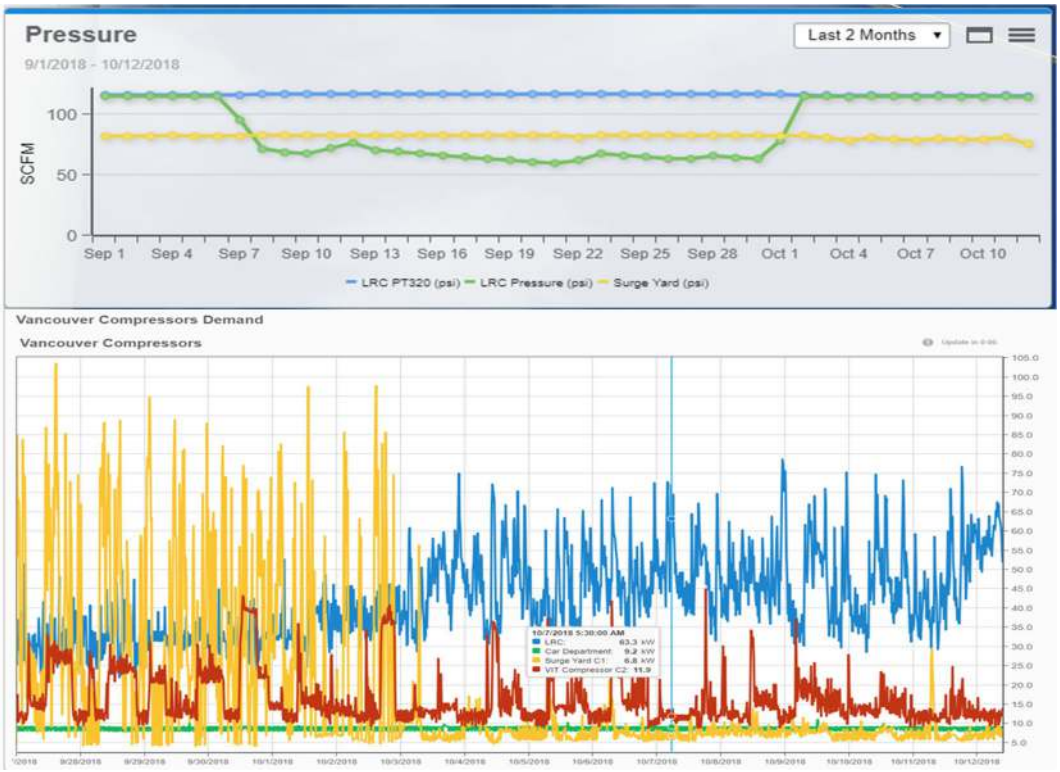

Figure 8 Compressed air close valve incident showing a drop in pressure throughout the incident period from the main line. The second graph shows the abnormal increase in power demand from the backup compressor.

Increased engagement leading to a culture of energy champions

Energy awareness is a key deliverable in CN's Strategic Energy Management Plan. The web dashboards have allowed staff from different departments to access the data in an easy manner. CN's Sustainability Group is now actively promoting the use of EMX dashboards in its regional sustainability workshops for CN's local energy champions (eco-champions). The group can easily open a web browser tab and provide a live demonstration without add-on software packages. These live demos are significantly increasing awareness about the tool and its uses for various staff. Success stories, published in CN's public affairs magazine, are also increasing awareness about the EMX dashboards. These stories highlight the operational value of the new EMIS and show field staff's pride in helping the organization to reduce waste and make a difference.

Survey responses from eight key staff in the Facility Maintenance, Operations and Sustainability departments indicate that the dashboards are positively contributing to energy awareness and conservation as shown in Figure 9. Surveys were equally divided between employees who had used the legacy EMIS tools and those who hadn't. Seven of eight participants find the information presented in the web-based dashboards to be very useful. Responses indicate that iterative design approach helped remove information clutter and improved the information flow. Five out of the eight participants believe that the dashboards have greatly enhanced their awareness of energy conservation at CN. Visual feedback about energy conservation actions are easily accessible through the EMX dashboards and reinforce this positive behaviour. Finally, when asked about their overall experience (low =1, 5 = high), participants gave the EMIS system an average score of 4.4. These results further suggest that the EMX dashboards are enhancing energy awareness and increasing staff engagement

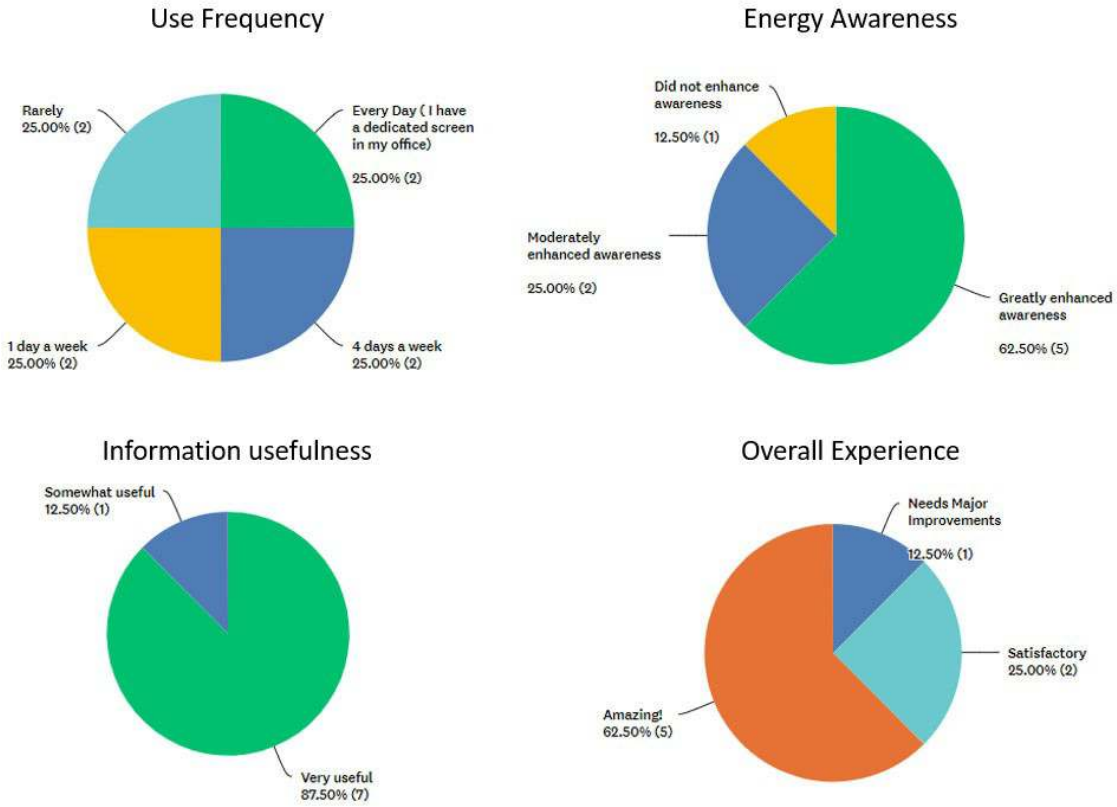

Figure 9- Survey conducted with eight participants on dashboards engagement on use frequency, awareness, information usefulness and overall utilization experience.

Next Steps

FM staff are responsible for large geographical areas and the new EMIS creates an opportunity to help them better manage their portfolios. Hamstrung by a vast portfolio of buildings and resources constraints, FM staff can use the EMIS to monitor additional buildings and equipment, as well as more effectively allocate resources to investigate abnormalities and energy waste. Moreover, equipment health and performance can be closely tracked to reduce travel costs and improve response time to incidents. This can be achieved by further integrating Building automation system with the EMIS as well as employing fault detection diagnostic system (FDD) at CN. It has been shown that the successful integration of alarm systems, FDDs and EMIS system can lead to effective energy conservation (Cook, Smith and Meier 2012)

The Energy Management Team has an ongoing objective to raise awareness about EMIS tools through training sessions and workshops. Although the tool is accessible through CN's intranet, the majority of building occupants are not yet aware that the tool exists. In efforts to increase exposure to the tool, the Energy Management Team is collaborating with CN's Corporate Sustainability Office to include EMIS tool awareness as part of the employee onboarding process. Further, success stories from dashboard investigations are being shared during monthly FM staff meetings as most sites have similar building types and equipment and energy conservation solutions can be easily replicated.

While the main focus of dashboard development was to aid FM staff in monitoring their buildings and equipment, it is equally important to engage the occupants of the monitored

buildings in reducing energy waste. Several studies have shown that exposing building occupants and field staff to dashboards and visualization will ultimately lead to an increase in energy awareness and establish an energy conservation culture that could rival savings achieved by technological measures (McMurry and Dooley 2017). CN's typical yard resembles a campus with different building types. The Energy Management Team is working on a pilot real-time aerial map to help better visualize the EUI and enhance interpretability for CN building occupants, as shown in (Figure 10). Research indicates that aerial map visualizations are easier to interpret compared to bar graphs (Kiernan et al. 2016). The aim is to make it easier for facility owners to question the performance of their buildings using a real-time color scale and, ultimately, detect abnormal energy waste.

Figure 10 Pilot EUI Map visualization at a typical large yard.

Conclusion

By focusing on accessibility and clarity for end users, CN's EMIS design is transforming data into meaningful insights and empowering staff to understand and conserve energy as part of their daily duties. The successful adoption of the web-based dashboards by FM staff was achieved by providing key real-time feedback and event notification on asset performance while also providing energy consumption impact insights. The improved accessibility of EMX dashboard has led to a threefold increase in monthly user activity compared to the legacy PC-based EMIS software package. The dashboards development took into consideration multiple feedbacks from CN's FM staff and their needs. This process helped shape energy and equipment insights that are easy to understand and meaningful without compromising data quality. The energy management team noted that field staff were more eager to adopt the new technology once an incident was caught and pinpointed by the EMIS. The web-based dashboards provide the opportunity for FM staff to independently identify and detect abnormalities in assets they manage on daily basis. This has lead to an increase in engagement with CN's efforts to reduce waste and create a culture of energy champions. With ongoing training efforts, the EMX

dashboards are playing a key role in empowering CN's staff to become energy conscious and ultimately help reduce energy waste across our network.

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