GATES-HILLMAN CENTERS
CARNEGIE MELLON UNIVERSITY
CASE STUDY

ENERGY EFFICIENCY
CARNEGIE MELLON UNIVERSITY

Carnegie Mellon University looked to SEMCO to provide solutions for their energy efficiency goals. SEMCO provided eleven custom-built variable air volume (VAV) air handling units complete with integrated 3 angstrom total energy recovery wheels to condition the Gates Center for Computer Science and Hillman Center for Future-Generation Technologies. All systems were provided with the necessary direct digital controls including custom programming and full electrical package – all factory tested.

"The fundamental design principle was to [realize an environmentally responsible project] without compromising the exceptional functional and experiential aspirations inherent to the visionary building program, but by actually enriching them. This goal was not only met — it has exceeded our initial expectations."

- Mack Scogin, Architect

SEMCO's 3 angstrom total energy recovery wheel.

Energy savings associated with the recovery wheels were monitored and accumulated over the first year of operation. Savings in excess of $90,000 were documented along with numerous other important operational and environmental benefits. The systems offer valuable Optimize Energy Performance points which helped the University complete the LEED certification.

In September 2009 Carnegie Mellon University officially occupied its new Gates Center for Computer Science and Hillman Center for Future-Generation Technologies. These 217,000 square foot facilities combine research space, 310 offices, conference rooms, laboratories, a 250 seat auditorium, and classrooms to house its internationally-recognized School of Computer Sciences.

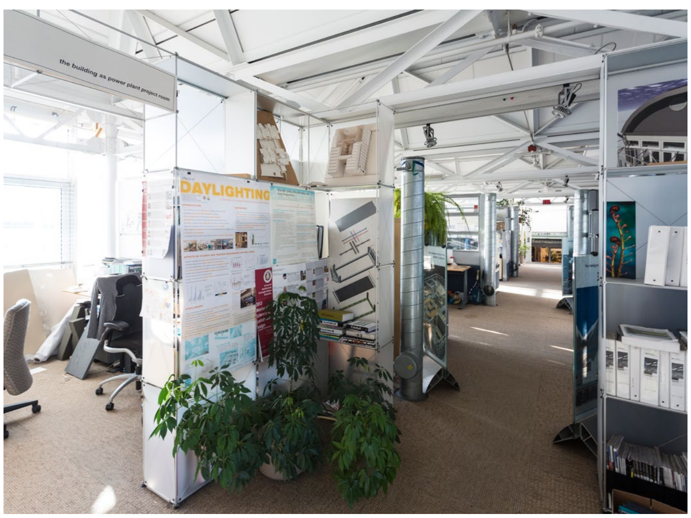
Energy efficiency and sustainable design practices were given the highest priority when designing these new facilities, with a goal of achieving at least a LEED silver certification from U.S. Green Building Council. Extensive day-lighting, green roofs and rainwater collection (gray water for toilet use) are just a few of the "green" innovations included within these facilities.

Gates Center with two of the roof mounted SEMCO systems.

Perhaps the most significant contribution to occupant comfort, environmental impact and operational cost was the decision to condition the buildings with custom built variable air volume (VAV) air handling units manufactured by SEMCO LLC. Eleven systems integrated the components found within a typical VAV system with SEMCO's 3 angstrom total energy recovery wheels, bypass dampers, DDC controls with programming tailored for the project and full electrical service.

In 2011, the Gates Center for Computer Science and the Hillman Center for Future-Generation Technologies were awarded LEED Gold certification, thanks, in part, to SEMCO's air handling units and enthalpy wheels which limit energy loss.

The SEMCO technology was not new to CMU. The technology has been extensively studied and tested at the University's Robert L. Preger Intelligent Workplace. SEMCO systems have also been successfully applied to other facilities on campus including the LEED Certified New House Dormitory and the prestigious Software Engineering Institute.



Robert L. Preger Intelligent Workplace

Given that the Gates and Hillman Centers would be the largest facilities integrating the technology, added instrumentation was incorporated into the DDC control systems for the sole purpose of measuring the impact of the total energy wheels. Performance monitoring completed over the first year of operation documented annual energy savings of more than $90,000 ($.42/ square foot). Additionally, 512 tons of carbon emissions and 533,000 gallons of cooling tower water use were avoided as a result of the total energy wheels.

DESIGNING AN ENERGY EFFICIENT VAV SYSTEM

There are numerous challenges associated with designing VAV systems. If properly designed and controlled they should maintain a comfortable indoor environment, control space humidity, deliver the proper quantity of outdoor air to all occupied spaces, avoid the use of excess reheat and operate energy efficiently.

To ensure proper ventilation to all spaces, the ASHRAE Standard 62 ventilation rate procedure is most typically employed. The design outdoor airflow quantity must be based upon the maximum occupancy levels, ventilation distribution effectiveness and numerous other design parameters. In addition, LEED facilities are commonly provided with 30% more than the ASHRAE 62 minimum ventilation requirement in order to obtain an additional LEED point. As a result the outdoor air volume required by VAV systems is typically far more that associated with other design approaches. Effective energy recovery is therefore highly beneficial to these systems.

Energy recovery wheels are particularly important during the heating season since the outdoor air fraction can approach 100% on the coldest days, as the VAV boxes are modulated to their minimum flow position for heating operation.

SEMCO worked closely with ARUP Engineers and the Carnegie Mellon construction team to design custom air handling/energy recovery systems that could provide effective total energy recovery when needed, bypass outdoor air when in full economizer operation and modulate the outdoor air fraction, when appropriate based upon a predetermined differential between indoor and outdoor carbon dioxide (CO_2) levels. The complex control algorithms, numerous damper operators and sensors required to allow the systems to function in this manner were factory installed and fully tested and commissioned prior to shipment. According to Guy Bacco, project manager for the installing contractor Ruthrauff Sauer, “This saved valuable time near the end of the project when we were on a very tight occupancy schedule and the remote monitoring really helped us through the commissioning process. The SEMCO factory controls were also less expensive than field installed alternative.”

The recovery wheel integration resulted in additional first cost savings for CMU. The technology offset 227 tons of chiller capacity and 135 boiler horsepower of heating requirements. Since the wheels can heat the outdoor air to above 50 degrees Fahrenheit, even at extreme design conditions, they allowed a costly integral face and bypass steam coil to be replaced by a traditional hot water coil. The effective latent recovery significantly reduced cooling coil condensate, provided some “free” humidification during the heating season and avoided frosting of the recovery wheel.

To conserve space, four of the largest air systems were mounted on the roofs of the Gates and Hillman Centers. System positioning, size and paint color were closely coordinated between SEMCO, the installing contractor and the building designers from Mack Scogin Merrill Elam Architects. To simplify maintenance, heated service corridors and pipe chases were designed into the SEMCO systems.

Given the important research work and collaboration conduced in these facilities, sound transmission and vibration were key concerns to CMU and ARUP engineers. Such concerns were merited since several of the executive conference rooms are located on the top floor directly under the large, SEMCO systems. The vibration and sound issues were effectively addressed by providing 4” thick casing walls, perforated inner liners where needed, supply and return air sound attenuators and a fully welded structural base fitted with proper isolation.

Figure 1 is provided to show a system layout typical of the four large rooftop systems. Seven smaller indoor systems were also provided by SEMCO as part of this project. The system shown is designed to deliver up to 40,700 cubic feet of air per minute (CFM) including up to 20,040 cfm of outdoor air. Components shown include the total energy wheel, the supply and return fans, fan frequency inverters, heating coil, cooling coil, filters, sound attenuators, dampers, control/electrical panel and service vestibule. The configuration of other systems were similar in scope, but customized to accommodate the installation needs and aesthetics of the facilities.

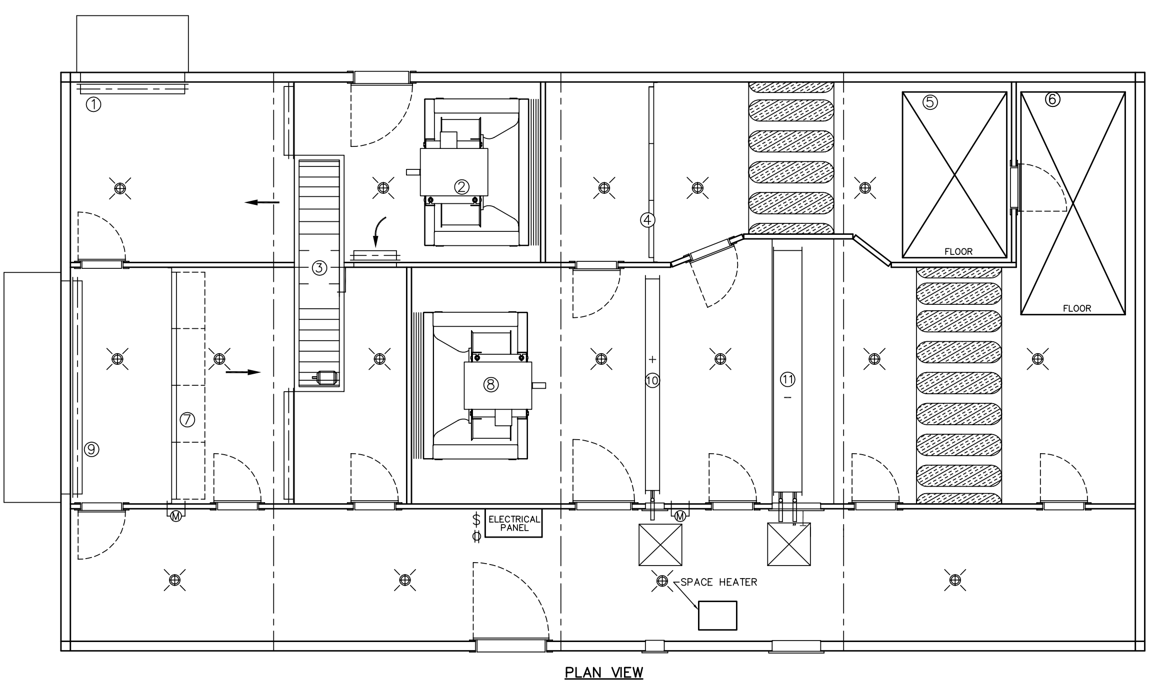


Figure 1: SEMCO general arrangement drawing for custom VAV air handling/energy recovery system.

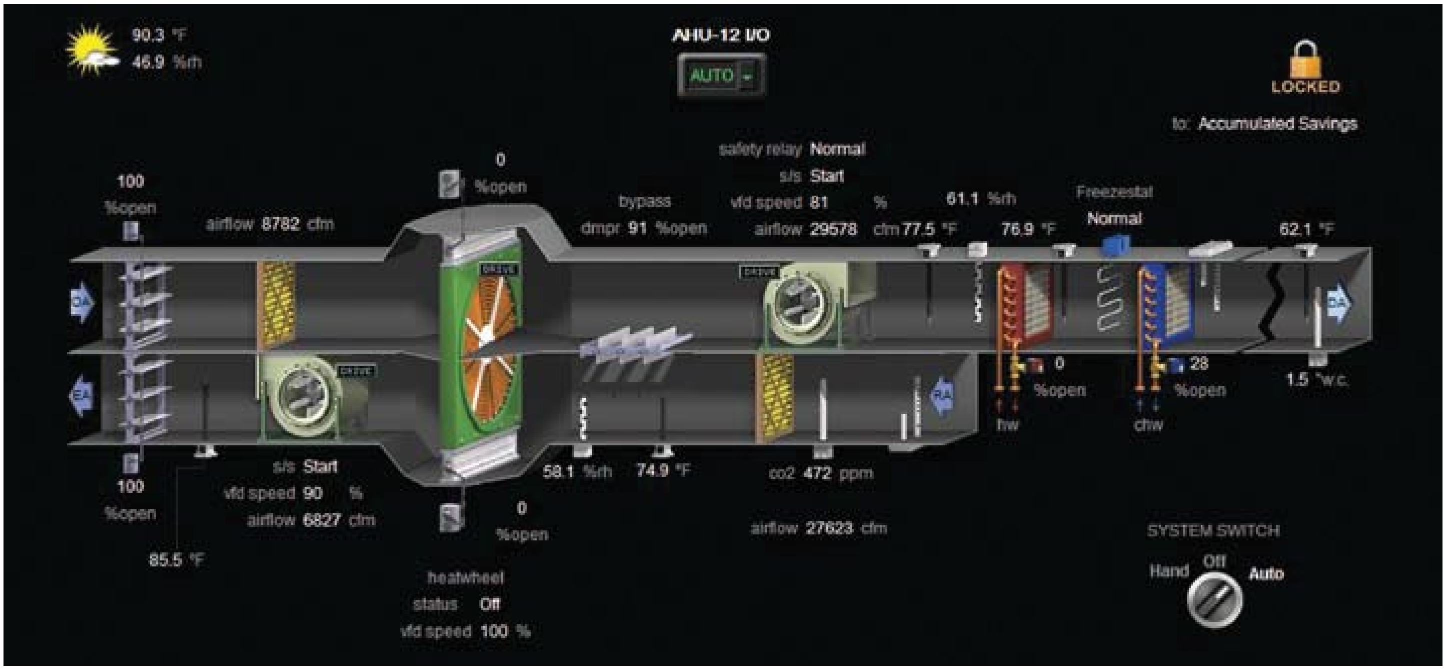


Figure 2: Screen shot of actual control system graphics shown sensors integrated with SEMCO systems.

ADVANCED CONTROLS INTEGRATION

The complexity of the controls associated with a well designed VAV system is very high for both the variable air volume boxes and the air handling units. To maximize occupant comfort, every room within the Gates/ Hillman centers was provided with a thermostat. Each thermostat is continuously monitored by the building automation system (BAS) to determine if heating or cooling is required at a given VAV box and how much "cold" air volume or hot water reheat energy is needed to satisfy the space conditions. The number of heating and cooling requests registered by the many VAV boxes throughout the facility are totaled, analyzed then used to determine the optimum temperature to be delivered to the ductwork by the SEMCO air handling systems. Control algorithms were carefully written to maximize free cooling and minimize the number of boxes where reheat is needed.

At the same time, controls integrated within the air handling automation systems (AHAS) monitor the duct pressure to deliver the amount of airflow needed by the VAV boxes at any point in time and to modulate the valves serving the cooling and heating coils to deliver the supply air temperature requested. Carbon dioxide sensors located throughout the building are compared and used to determine the amount of outdoor air to be delivered at any moment in time. Systems to monitor the supply, return and outdoor airflows provide control signals which are used to modulate dampers and satisfy the ventilation needs.

Temperature and humidity levels of the outdoor, return and supply airstreams as well as those leaving the total energy wheels are monitored and used to calculate enthalpy conditions. These values are used to determine when the systems should be in a free cooling or "economizer" mode, how much outdoor air is required for this purpose and whether or not energy recovery is desired. The speed of the recovery wheel is controlled to provide only the amount of recovery needed and, when the recovery is not needed, bypass dampers are opened around the wheel to save fan energy.

Figure 2 shows a snapshot of the main controls graphic for one of the rooftop mounted systems. This graphic shows many of the control and monitoring sensors integrated into the SEMCO systems.

Given that the complexity of the controls required by the air handling systems with integrated total energy recovery requires knowhow that is not generally a core competency of the BAS contractor, it was highly beneficial that the AHAS controls be designed, installed and tested by SEMCO. Excellent coordination and seamless integration between the BAS and AHAS control systems was achieved at the Gates/Hillman centers due to the fact that the BAS system chosen by Carnegie Mellon and the SEMCO preferred control platform were both Automated Logic Controls.

As a result, the two separate control programs (BAS and AHAS) were developed independently then merged into a single database utilized by the CMU Facilities Group and monitored remotely by both SEMCO and the local Automated Logic office. As previously mentioned, the factory tested controls reduced project cost, cut the installation time, and streamlined the commissioning process.

PERFORMANCE AND ENERGY MONITORING

Given that the SEMCO 3 angstrom total energy wheel integration offered the most significant economic benefit of all "green building" technologies incorporated into the Gates and Hillman centers, and since documenting energy efficiency and environmental impact are key objectives of Carnegie Mellon, provisions were made to measure and accumulate "real-time" performance.

Knowing the outdoor and exhaust airflows through the total energy wheels, the temperature and humidity levels within each of the four airstreams around the wheels and the pressure loss across each side, the recovery performance at any point in time is known. A graphical window was incorporated into the main control systems database reporting this data in "real time" shown as recovery effectiveness, current and accumulated heating and cooling savings, tons of carbon emissions reduced and gallons of cooling tower water eliminated.

Figure 3 summarizes the first year energy savings and environmental impact associated with the SEMCO total energy recovery wheels. As shown, more than $90,000 in accumulated annual energy savings were recorded, which has been projected to amount to more than $2,000,000 in savings over a 20 year life cycle. According to Andrew Riley, Carnegie Mellon Project Manager for the Gates and Hillman Centers, the reduction in chiller and boiler capacity from the central plan is valued at approximately $310,000 by the University. These savings alone covered most of the added cost associated with the integration of the total energy wheels into the air handling systems.

Benefits provided by SEMCO Energy Recovery Wheels at the Carnegie Mellon Gates and Hillman Centers (Actual monitored and Accumulated data)	
Annual energy savings measured	$90,812
Chiller capacity reduction (design day)	217 tons
Boiler HP reduction (design day)	135 boiler HP
20 year energy savings (reflects inflation)	$2,185,000
Cooling tower water savings due to wheels	533,700 gallons/year
Reduced carbon emissions due to wheels	512 tons/year

Figure 3: Summary of first year energy savings and environmental impact.

During mid January of 2009, outdoor air conditions reached -6°F. At this extreme condition, the outdoor air was preheated to over 53°F by the energy wheels alone allowing the building to be conditioned without any heat being provided by hot water coils located within the air handling units. Based on this observation, it is likely that these hot water coils will seldom be utilized.

The accumulated heating and cooling energy savings recorded can be directly translated into tons of carbon reduction at the power plant and gallons of water saved at the cooling tower. Environmental impact is a top priority for Carnegie Mellon. The University recently joined the International Sustainable Campus Network indicating a commitment to implementing "best practices" in sustainable building design and sharing experiences and data with network members globally.

IMPACT ON LEED CERTIFICATION PROCESS

Design features of the SEMCO air handling systems with integrated energy recovery and controls will significantly contribute to the number of LEED points awarded the project. Allowing the outdoor air to be provided at 30% above the ASHRAE Standard 62 minimum, measuring and maintaining proper outdoor airflows, monitoring space temperature and humidity, greatly reducing water consumption at the cooling tower, and substantially reducing energy use compared to that of an ASHRAE 90.1 baseline system will result in LEED point credits.

To estimate the number of LEED points that may likely be achieved out of the 10 possible points offered by the Energy and Atmosphere Optimize Energy Performance section, energy modeling representative of the Gates and Hillman centers was completed using the Carrier HAP energy simulation program. The modeling compared a baseline VAV system without energy recovery (not required by ASHRAE 90.1) against the same building using the integrated recovery wheels and adjusted to reflect the measured energy savings. The modeling also reflects the increased day lighting incorporated into the architectural design. The results of these analyses are presented by Figure 4.

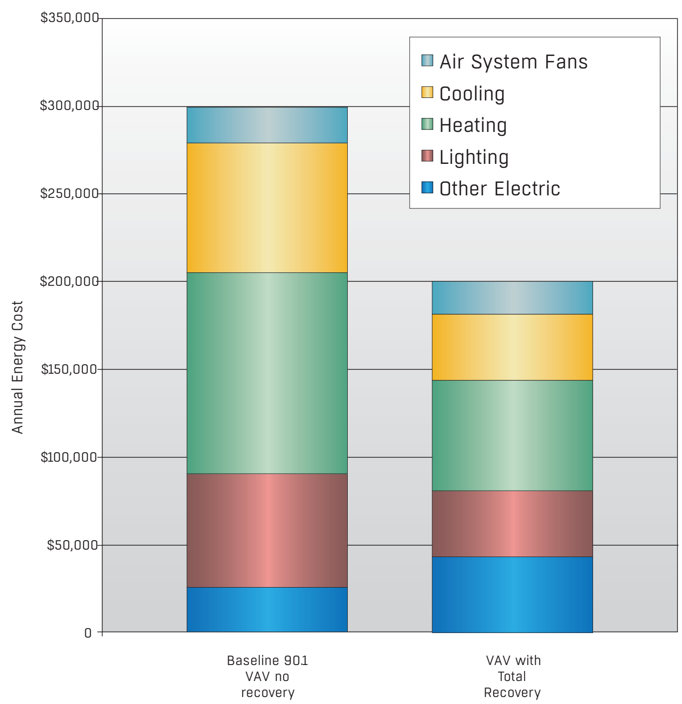


Figure 4: Energy modeling to compare baseline ASHRAE 90.1 VAV building with VAV plus total recovery and increased day lighting.

The progressive architecture design of the Gates and Hillman centers employed a façade of 52% solid gray zinc panels and 48% glass. In fact, each of the 310 offices has a window. This natural day lighting enhances the building environment and greatly reduces the energy required to light the facility but increases the heating load to be processed by the HVAC system.

Based on the results of this modeling, which reflects the extended occupancy hours of an active University environment and a cost from the campus physical plant of $.10 per cooling ton and $1.2 per heating therm, a 34% reduction in total building energy was projected. This reduction would qualify for a total of 7 Optimize Energy Performance LEED Points. The impact of the total energy recovery addition alone was most substantial, accounting for 6 of the 7 LEED points, providing a 28% reduction.

These results highlight the obvious economic, operational and environmental drivers for employing SEMCO air handling systems with integrated total energy recovery and controls for all buildings seeking LEED certification and designed to include variable volume (VAV) HVAC systems.

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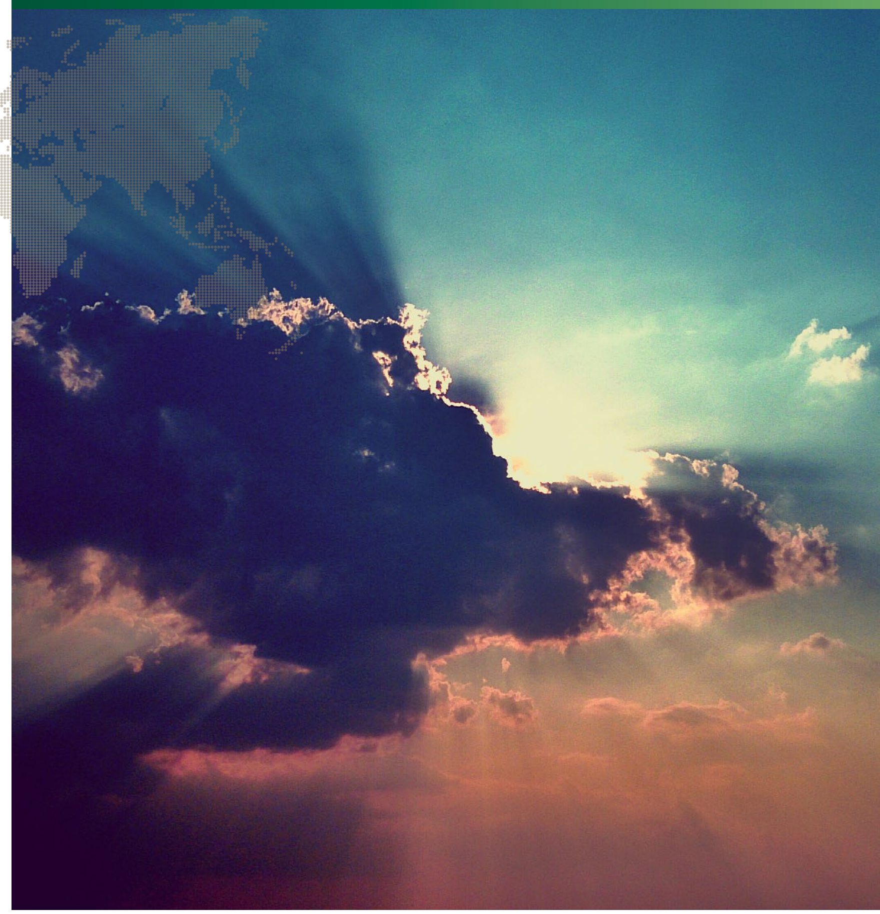

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