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New York

Acoustically Protected Natural Ventilation

An untapped opportunity for American cities

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Acoustically protected natural ventilation offers significant benefits to building occupants and owners by providing fresh air, connection to the outdoors, and low-energy cooling while mitigating troublesome noise. Although there are international project precedents and even manufactured products, this strategy is virtually unheard of in North America.

This paper introduces North American audiences to acoustically protected natural ventilation (AP-NV) and encourages its adoption. We first review project and product precedents before demonstrating its viability by sharing a prototype tested in a typical New York loft office. Acoustic and airflow measurements confirm the efficacy of the strategy, while survey results confirm the demand from occupants.

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What is acoustically protected natural ventilation?

Natural ventilation (NV) is the supply of outside air – typically unconditioned – directly into a space through the façade. At minimum, NV may be provided to ensure good air quality and a healthy environment. Building occupants and owners have become even more aware of the importance of ventilation for indoor air quality as a result of the COVID-19 pandemic (Agarwal et al., 2021, Park et al., 2021). NV can also be used for cooling, drawing cooler outside air into the space to remove heat from people, light, and equipment. NV for cooling typically requires higher flowrates than NV only for air quality, and is the main focus of this paper. Strategies that use very low pressure exhaust fans (less than 20 Pa / 0.08" w.c.) we still consider as 'fan-assisted' natural ventilation – key is that ventilation is introduced directly through façade openings in the occupied space.

The primary reasons for providing NV are to increase occupant satisfaction with their indoor environment. Allowing occupants to control ventilation directly has been shown to increase productivity (Loftness et al. 2003). Buildings with NV have further shown improved concentration while reducing feelings of depression, respiratory symptoms, and eye irritation among their occupants (Hummelgaard et al. 2007, Brager and Baker 2009, Yun et al. 2008, Leeman and Bordass 2010).

NV can also save energy due to reduced use of mechanical equipment, but this is not a primary driver. Transsolar typically finds that natural ventilation can save 1-5% of annual energy costs for a new construction or major renovation.

However, the outside environment – especially in dense urban areas – can be full of auditory distractions and loud noises. Noise from traffic, sirens, buses, construction, people, cleaning equipment, and more can impact our happiness, wellness, and productivity. Undesired noise from outside can force occupants to close windows that they would otherwise have open. Reducing outdoor-indoor noise transmission is therefore critical to increasing the feasibility and use of natural ventilation in louder environments such as New York. Figure 1 illustrates the challenge as experienced in Transsolar's office on 23rd St. in New York.

This challenge applies to any interior use with noise-sensitive activities, such as writing, reading, meeting, sleeping, watching TV or movies, etc. Since nearly all buildings include some variation of these uses, the broad applicability of AP-NV is clear: schools, offices, libraries, apartments, houses, and many other building types can benefit from AP-NV.

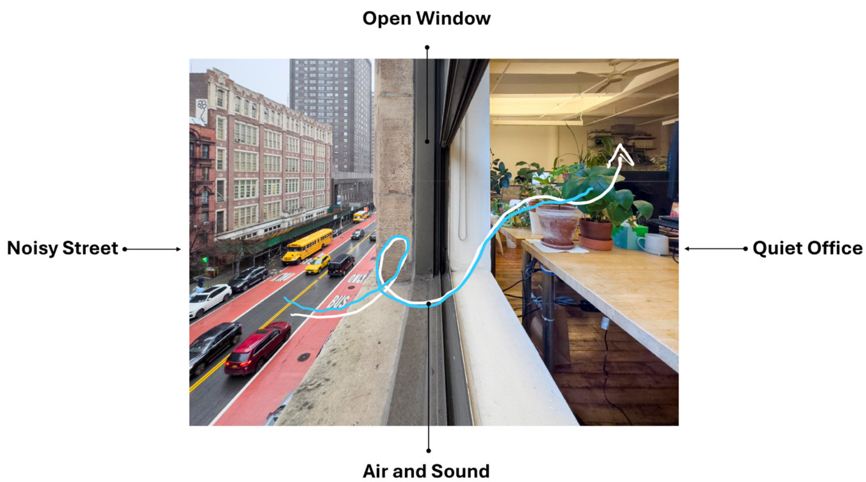

Figure 1. **Urban noise transmission through an open window**

In addition to noise, security can also be a barrier to natural ventilation (Roetzel 2010, Heiselberg 2004). Natural ventilation at night can be very beneficial – in residential spaces occupants benefit from sleep with open windows, and in commercial spaces 'night cooling' via natural ventilation can cool a space in preparation for the next day. Unprotected window openings, however, create an obvious security concern for people sleeping and unoccupied building space, as intruders can enter through open windows. AP-NV openings nearly always create a protected opening; hence security risks are also mitigated through the integration of acoustic ventilation openings.

Suitability of climate and air quality

Most North American climates have significant potential for use of natural ventilation. A well-designed natural ventilation system allows spaces to operate in NV for a broad temperature range. Rather than 'perfect spring day' conditions of 62-70°F, NV can be extended to cooler temperatures by preventing excessively high flowrates (e.g. cracking windows) and to warmer temperatures by ensuring flowrates are very high and using ceiling fans to provide comfort at higher indoor temperatures. With these strategies, NV can often be applied for outdoor air temperatures ranging from 50-76°F.

Figure 2 shows how often and when outdoor air temperatures fall within these ranges for three American cities that might not be considered 'ideal' climates for natural ventilation. Each dot on the chart represents one hour of the year within this range. Natural ventilation periods are typically during the day in spring and fall, and at night in the summer. 44% of the year falls in this range for New York, 40% for Chicago, and 37% for Houston. In cooler climates such as New York and Chicago, this percentage will actually increase with predicted climate change, as more cool winter days move in a range suitable for natural ventilation.

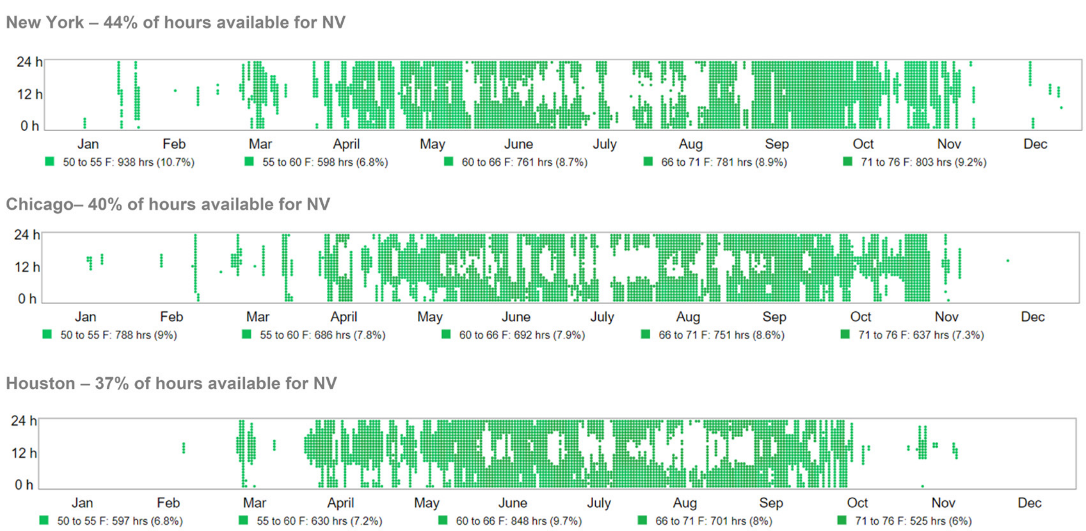

Figure 2. **Annual hourly periods with 50-76°F for New York, Chicago, and Houston (TMY3 data)**

Air quality is often raised as a concern for natural ventilation in urban environments. In most North American cities, however, outdoor air quality exceeds any required health standards and is much better than indoor air quality. In most situations providing unfiltered outdoor air is beneficial and does not pose a risk to occupants. Figure 3 shows an example of 2022 hourly PM 2.5 (fine dust) data from the EPA. Each city's annual average falls below the new 2024 annual concentration threshold of 9 μg/m³ and 88-99% of hours fall below the EPA's 24-hour threshold of 35 μg/m³ (from their latest rules issued in February 2024).

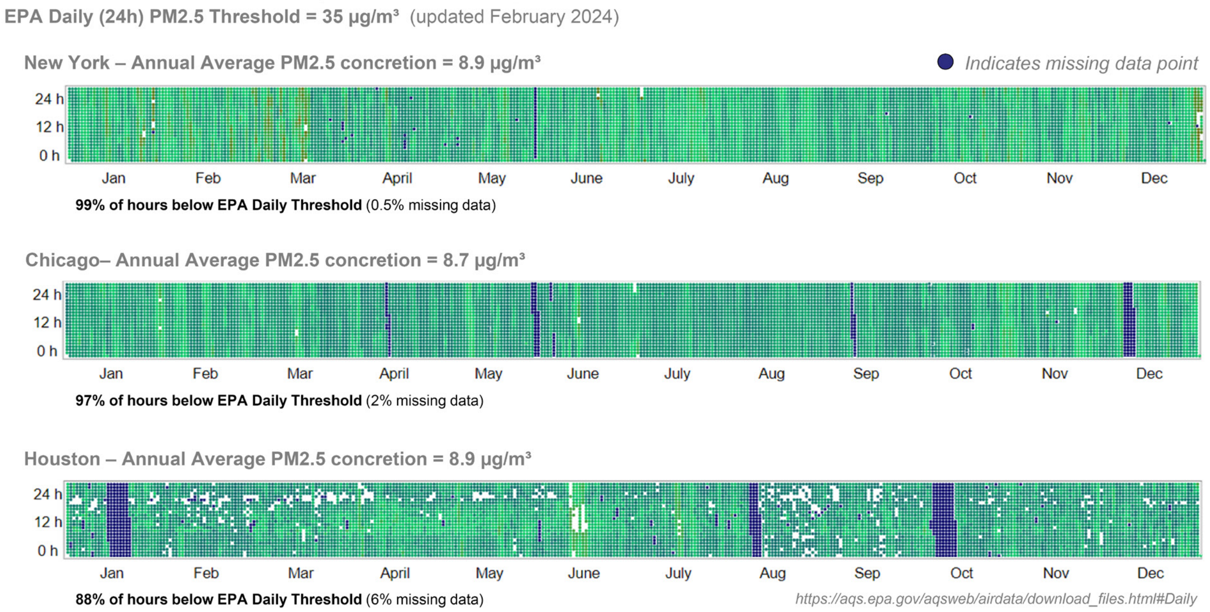

Figure 3. **2022 PM 2.5 concentrations between 0 and 35 micrograms/cubic meter for New York, Chicago, and Houston (EPA Airdata)**

A small set of urban locations (directly adjacent to highways, for example) can pose air quality risks and need to be assessed individually. Periods of poor air quality due to PM2.5 from wildfires are also increasing in most cities. Lastly, some cities have seasons with extremely high pollen counts, resulting in PM10 particulates that create an indoor dust nuisance and pose a health risk for those with pollen sensitivities. Unfiltered natural ventilation should be avoided when these risks are present – however it can still be used at times without air quality issues. Even with significant increases in poor air quality days in some cities due to wildfires, many days will continue to have suitable air quality for natural ventilation. Addressing specific locations or time periods where air quality is a concern is beyond the scope of this paper, but a very low pressure drop filter incorporated in an acoustic vent could be a future solution to this challenge.

Project Precedents

AP-NV precedents are mostly in northern Europe, where the cool climate is especially amenable to the use of natural ventilation. Here we review two case studies in detail, followed by a survey of additional precedents.

Figure 4 shows exterior views and the AP-NV strategy for the Testo AG headquarters building in Titisee-Neustadt, Germany. This office building was completed in 2011, designed by Sacker Architects. Transsolar provided sustainability consulting while Mosbacher + Roll facade technology GmbH acted as façade consultant.

Loud traffic noise from the adjacent highway resulted in outdoor noise levels as high as 75 dB, creating the need for an acoustic natural ventilation concept. Two different types of acoustic natural ventilation openings were integrated: flat facade openings (A) and sawtooth façade openings (B). Both incorporate acoustic material within a ventilation grille, with an opaque flap behind for user control. The noise reduction was estimated by calculation as 4-10 dB, depending on the louver spacing and depth.

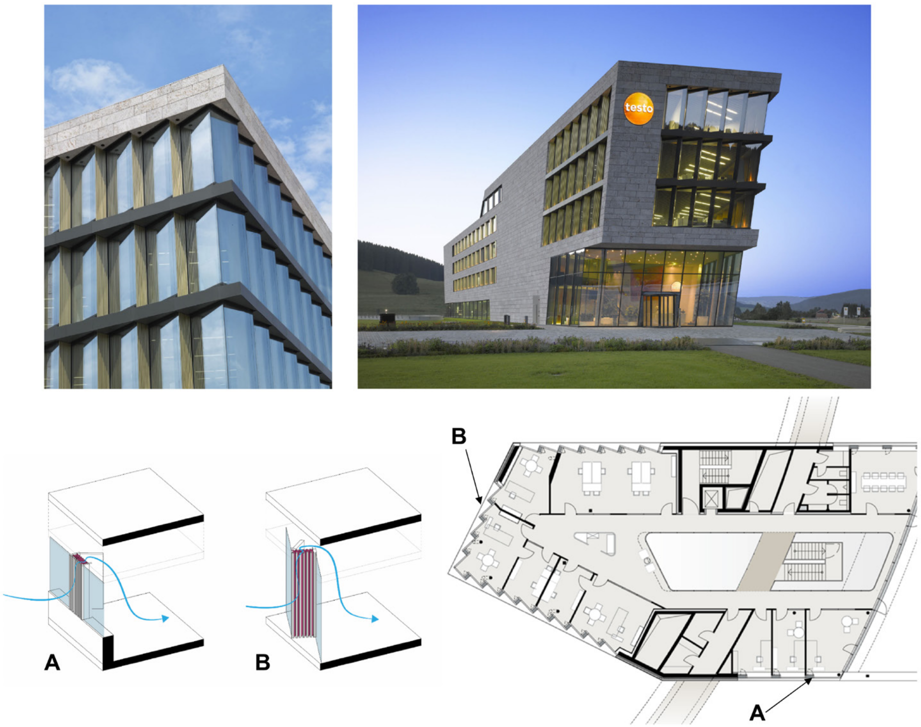

Figure 4. Exterior views, AP-NV strategy, and typical floor plans for Testo AG Headquarters, Celsiusstraße 1, 79822 Titisee-Neustadt, Germany. Photographs courtesy of Heinze by Miguel Babo Photography.

Figure 5 shows exterior views and the AP-NV strategy for the Ventspils Music School and Concert Hall in Ventspils, Latvia. This building was completed in 2019, designed by haascookzemmrich STUDIO2050 and Studio MSV with sustainability consulting by Transsolar. AP-NV is provided in all of the music rehearsal rooms, where acoustic isolation from the outdoors is especially critical. As at Testo, ventilation is provided through a louver lined with acoustic material, with an opaque operable flap behind for user control. In this case the louvers are oriented horizontally rather than vertically.

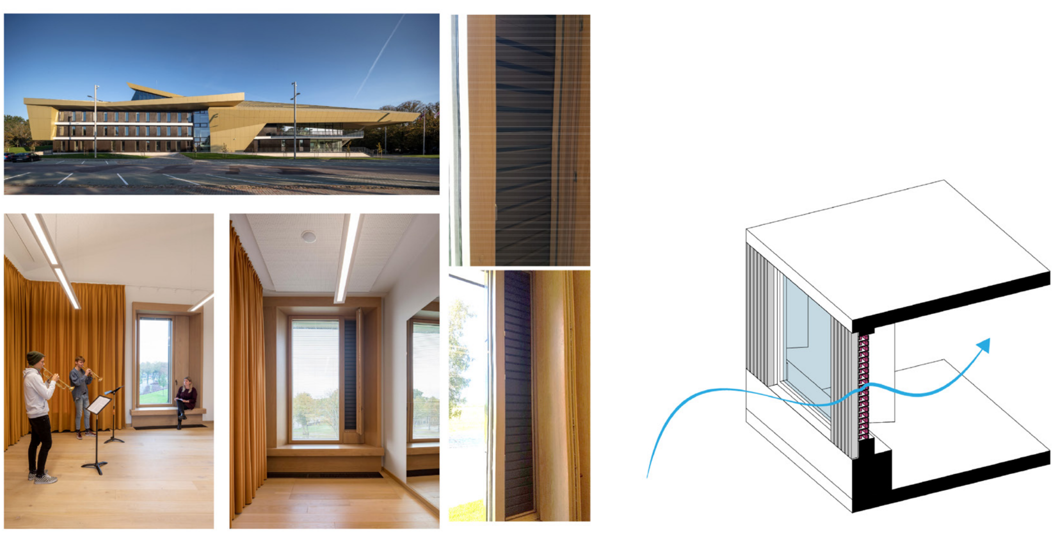

Figure 5. Exterior views, interior views, and AP-NV strategy for Ventspils Music School and Concert Hall, Ventspils, Latvia. Photographs courtesy of Adam Mørk.

Table 1 summarizes additional project precedents and Figure 6 illustrates the same precedents. Many precedents are in the UK, where natural ventilation is often used, even in commercial buildings. Building types are diverse, including schools, retail, and offices, but always in response to an acoustically sensitive program, a noisy outdoor environment, or both. Custom solutions and off-the-shelf products are employed equally often. Almost all solutions are a combination of weatherproof louvers with acoustic baffles, typically with an opaque flap behind for user control. Motorized and automated solutions are more unusual, but also used. In addition to the acoustic louver, the Hackney City Academy includes a secondary exterior glass screen, which should also provide some modest sound reduction. Acoustic reduction from a glass screen is also often cited as a secondary benefit of double façade design (but not the primary reason for designing a double façade). Such double facades are beyond the scope of this paper.

Table 1. **AP-NV project precedents**

Project Name	Location	Architect	Natural Ventilation Engineer	Program	Year	Motivation for Acoustic Natural Ventilation	Custom Solution or Product	Description of Final Form
Hackney City Academy	UK	Studio E Architects	Max Fordham	School	2009	Classroom environment	Custom	Acoustic Louvers with External Screen: External glass screen mounted about 1m from the façade (not sealed) 100mm deep weatherproof acoustic louver Bottom-hung window operated by a motorized chain actuator Splitter Attenuators in Bulkhead: High free-area weather louver 99mm long, approximately 50% free area builders-work splitter attenuator Bottom-hung insulated panel operated by a motorized chain actuator
Locking Castle School	UK	David Morley Architects	-	School	2005	Classroom environment	Custom	300 mm deep weatherproof acoustic louver 90° acoustically lined bend Internal insulated door – manually operated
Costa eco-pods	UK	Zero Energy Architecture	XCO2	Coffee Shop	2015	To fit with company's message	Product	Manufacturer: Breathing Buildings
Infinity Here East Data Centre	UK	Hawkins\Brown	BuroHappold	Data Center	2012	To prevent noise from the building's plant and machinery from disturbing local residents	Product	Manufacturer: Caice Acoustic louvers
Cornwall Energy Recovery Centre	UK	David Butterworth	SLR Consulting	Waste Incinerator	2017	Noise levels in the sensitive surrounding environment	Product	Manufacturer: Caice Acoustic louvers
Testo AG	Germany	Sacker Architects	Baumgartner / Transsolar	Office Building	2011	Nearby road noise	Custom	Vertically oriented 15 cm chevron baffles to the side of the window with an insulated, opaque, operable door and horizontal slats to the side of the window with an insulated, opaque operable door.
Music School and Concert Hall, Ventspils	Latvia	haascookzemmrich STUDIO2050 and Studio MSV	Transsolar	Music School	2019	Noise attenuation from external environment and Noise reduction from music practice to surrounding environment	Custom	Horizontally-oriented C channel with acoustic lining with an insulated, opaque, operable door.

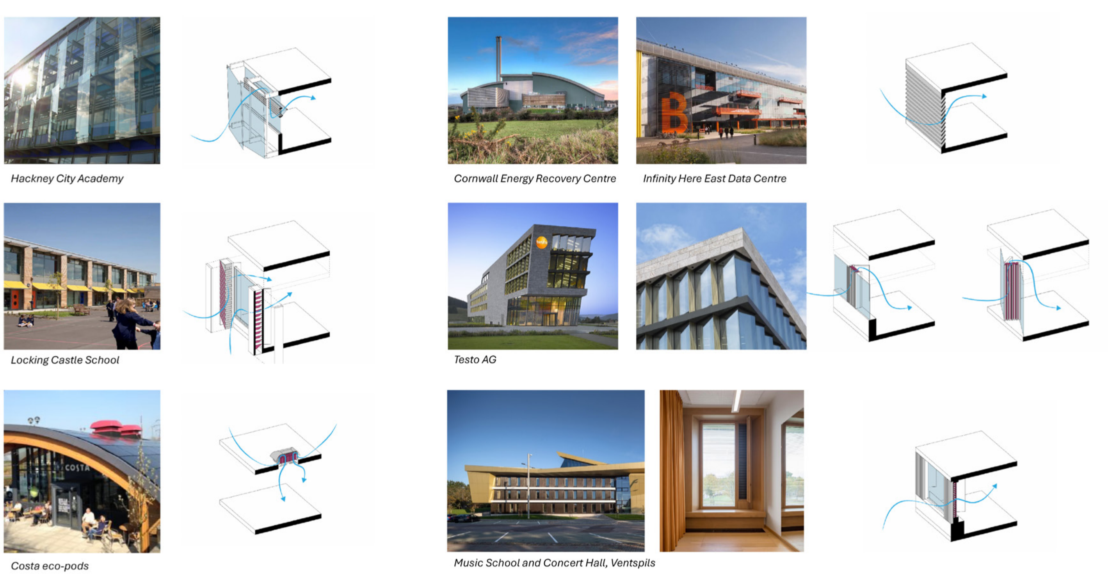

Figure 6. **Views and configuration of project precedents**

Manufactured Products

There are a variety of manufactured products either specifically designed for AP-NV or which can be adapted for AP-NV. Figure 7 shows the typical configuration of these products. Trickle vents are normally installed at a window sill or head and are only large enough for minimum ventilation for air quality, not cooling. The trickle vent is lined with a sound-absorbing material.

Acoustic wall vents line a weatherproof louver with sound-absorbing material. Variations in geometry usually aim to increase the surface area of sound-absorbing material, increasing the noise reduction benefit. However this can also result in more pressure drop, and hence less airflow and cooling. The trade-off between pressure drop/airflow/cooling and noise reduction must be evaluated for each design.

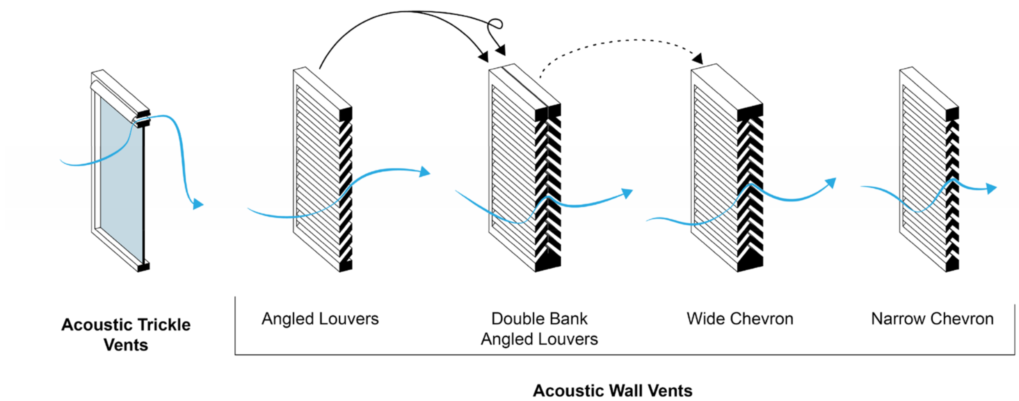

Figure 7. **Typical configurations of manufactured AP-NV products**

Table 2 provides an overview of select AP-NV products. Many products are from UK manufacturers, again due to the prevalence of NV in the UK. Mineral wool or glass fiber is typically used for sound absorption. Most products are only manually adjustable, but there are more sophisticated products (TEK and Resivent Zero) that can be automated. Acoustic louvers from major U.S. manufacturers such as Greenheck or Ruskin, while not marketed for this application, can also be used for AP-NV. They have to be assembled in a detail with an insulated and gasketed door (or damper) behind the louver itself.

Sound attenuation data is difficult to compare across products because it not consistently measured following the same standard. Trickle vents and other products designed for minimum outside air often report a simple indoor-outdoor attenuation of 40 dB or more. The small free area of these products allows them to achieve fairly high sound attenuation.

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Table 2. **Overview of acoustic NV products**

Product Name	Type	Weather Control	Air Flow Control	Application	Acoustic Attenuation Material	Acoustic Attenuation Geometry	Installed Location	Noise Attenuation	Average Transmission Loss	Notes	Product Image
TEK	Double Bank Angled Louvers	Angled louver	Full electric operation of trickle setting	Cooling + Min OA	Mineral wool/Glass fiber	Louver or chevron	Next to window	See Figure 8	22	UK based	
Resivent Zero	Wide Chevron	Angled louver	Remotely	Cooling + Min OA	-	-	Window	STC 19-36	-	UK based	
Passivent	Wall Vents	Angled louver	Manually adjusted	Cooling + Min OA	Mineral wool	Single or double internal acoustic chevrons	Façade , windows	Rw 22	-	UK based	
Rytons	Wall Vents	Angled louver	Manually adjusted	Min OA	Foam duct lining	Duct	Facade	43 dB	-	UK based	
Titon	Trickle Vents	Curved canopy	Manually adjusted	Min OA	Foam	Linear vent	Window slots	$D_{n,e,w}(C_{tr})$ = 44 (−2;−3) dB	-	UK based	
RW Simon Ltd	Trickle Vents	Curved canopy	Manually adjusted	Min OA	Vent lining	Foam/Recycled foam	Window.	32-42 dB	-	UK based	
Greenwood	Trickle Vents	Curved canopy	Manually adjusted	Min OA	Vent lining	-	Facade, windows	45dB	-	UK based	
Brookvent	Trickle Vents	Curved canopy	Manually adjusted	Min OA	Vent lining	Foam	Window	40-47 dB	-	UK based	
Breathing Buildings	Wall Vents	Angled louver	Manually adjusted	Cooling + Min OA	Mineral wool	Linear baffles	Plenum/Façade	-	-	UK based	
Greenheck	Wall Vents	Angled louver	No adjustment	Cooling + Min OA	Mineral wool	Angled louvers/chevrons	Façade	STC 8 - 18	7	US Based	
Ruskin	Wall Vents	Angled louver	No adjustment	Cooling + Min OA	Mineral Wool	Angled louvers/chevrons	Façade	See Figure XX	7	US Based	
Dowco	Wall Vents	Angled louver	No adjustment	Cooling + Min OA	Mineral Wool	Angled louvers/chevrons	Façade	See Figure XX	17	US Based	
awv	Wall Vents	Angled louver	No adjustment	Cooling + Min OA	Mineral Wool	Angled louvers/chevrons	Façade	See Figure XX	9	US Based	
Reybaers Aluminum	Window	-	Manually adjusted	Cooling + Min OA	None	None	Window	9 dB	-	Arup developed window brought to the EU market. Belgium Based	

Louver products often report either Sound Transmission Class (STC) (ASTM International 2010) or Outside Inside Transmission Class (OITC) (ASTM International 2022) as described in the metrics section below. OITC places more weight on lower frequencies (e.g. 80-800 Hz) and extends to a lower range for frequencies. Simple louver products can have STC as low as 10, while AP-NV products are often approach an STC of 20. Figure 8 shows sound transmission loss of select products for specific octave bands. The TEK product has the highest loss, but at the lower frequencies that are emphasized for OITC off-the-shelf louvers such as Dowco have similar performance.

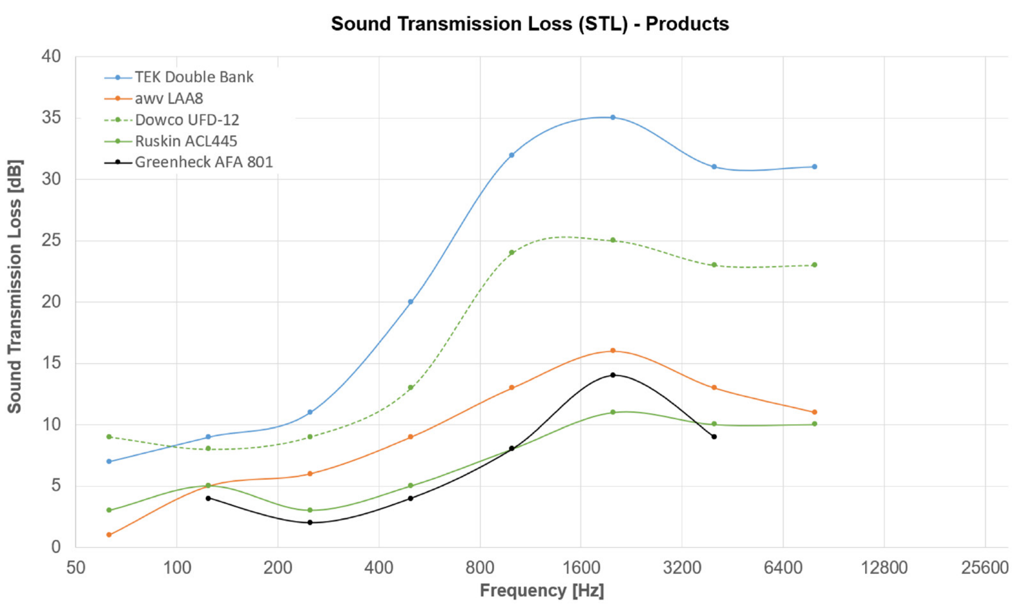

Figure 8. **Sound transmission loss in different octave bands as reported by different manufacturers. Note that the measurements are not all according to the same test standard.**

This review of both project precedents and manufactured products shows that solutions for acoustic NV exist and have been successfully utilized many times outside of North America – enough to establish a market for acoustic NV products. The acoustic performance of many products has been characterized and demonstrates that they accomplish meaningful sound attenuation.

Transsolar New York Survey

To confirm the potential value of AP-NV in our office, we surveyed staff working regularly in the office on their experience and preferences for naturally ventilating the office. The survey was conducted anonymously online during the week of January 22, 2024. 8 people responded.

Figure 9 shows survey responses regarding natural ventilation in the office. The sample size is very small, and limited to Transsolar engineers likely biased toward natural ventilation. Regardless, they show a clear demand for natural ventilation, but a need for sound protection, with more than 80% of respondents indicating noise from windows impacts productivity ‘sometimes’, ‘often’, or ‘all the time’, and over 60% indicating they are ‘somewhat likely’ or ‘very likely’ to close a window due to noise.

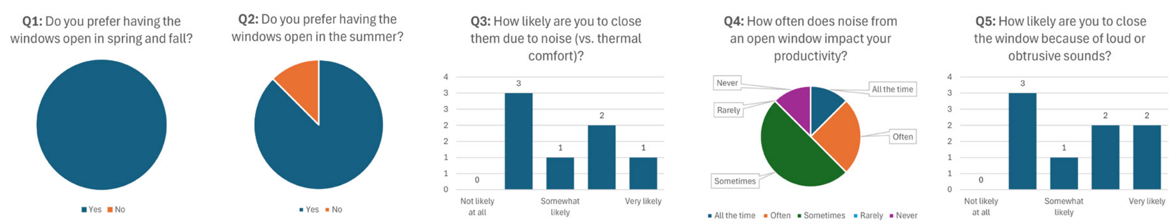

Figure 9. Survey responses regarding acoustic NV in the office

In open-ended responses, respondents noted qualitative reasons for opening windows such as “feeling of connection to outdoors”, “breeze of fresh air”, and “air quality, temperature control, noise reduction”, but also “I also don’t like looking through glass. I will open the windows to be able to look outside and rest my eyes, glassless”. Respondents noted that specific sounds that affect their work include construction noise (jack hammering), traffics sounds (including sirens), and people shouting.

Figure 10 shows survey responses regarding natural ventilation at home. The results show that noise sensitivity is an even greater issue at home, with over 80% of respondents saying they are ‘somewhat likely’ or ‘very likely’ to close windows due to noise, and all respondents indicating noise is ‘somewhat important’ or ‘very important’ when selecting a place to live.

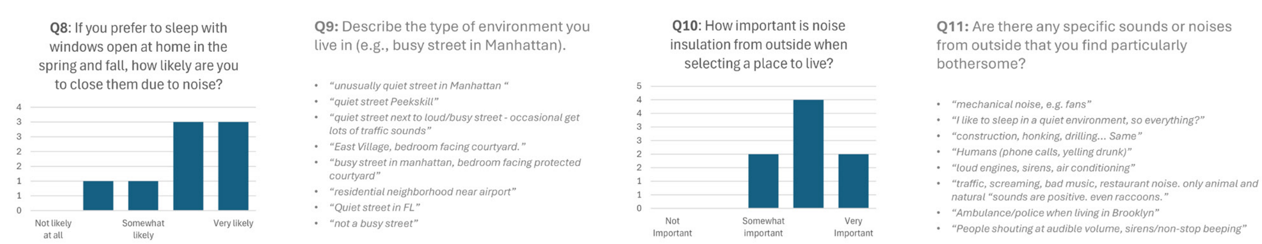

Figure 10. Survey responses regarding NV at home

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In open-ended responses, respondents identified many of the same sources of bothersome noise as at the office, with the addition of mechanical noise (fans and air conditioning units). Respondents also noted the positive value of natural sounds such as birds and even raccoons – which are likely more available and noticeable at home than at the office. In addition to closing windows in response to noise, respondents indicated they will run fans to create white noise or play music.

This very small survey shows the demand for AP-NV from office workers working in Manhattan and mostly living in New York City.

Transsolar New York Prototype

Because we cannot identify any North American examples of intentional design for AP-NV, we designed, installed, and measured the performance of a simple AP-NV prototype in our own office in Manhattan. The goals of the prototype were (a) to experience the qualitative effect of such inserts for ourselves in our own space; (b) to measure the achievable flowrate and acoustic performance; and (c) to introduce the New York and North American design community to this ventilation strategy.

The prototype is a 2'-9" wide x 12" high x 6" deep open window insert with a bird screen that slides into the opening created when the lower sash of the existing window is opened upward. We designed and fabricated several different acoustic vents that can be swapped into this insert. The vent is sized for 150-200 cfm of inward airflow, based on a maximum air velocity of 200 fpm through the free area of the vent, resulting in a free area of 1 square foot. The airflow target is based on a target of 3 air changes per hour (ach) for cooling-based natural ventilation; our experience shows that in northeastern U.S. climates this is typically an appropriate target flowrate. Three vents at 167 cfm each would be required to reach 500 cfm, which is 3 ach for this office. The remaining window can be used for an exhaust fan that creates the negative pressure necessary to draw air in through the vents.

Figure 11 shows the geometry of three different acoustic vents tested: an initial chevron design with acoustic material on one side of the chevron, a modified chevron design with acoustic material on both sides of the chevron, and a jogged-path design, with a longer airflow path lined with acoustic material. The vent is constructed of plywood with 1" thick mineral wool board (Rockwool Comfortboard 80) as the acoustic material. Both chevron designs have an airflow path length of 0.5 feet, whereas the jogged design has a longer path of 1 ft. The chevron, modified chevron, and jogged designs have total surface area of acoustic material of 1.7, 3, and 2.5 ft2, respectively.

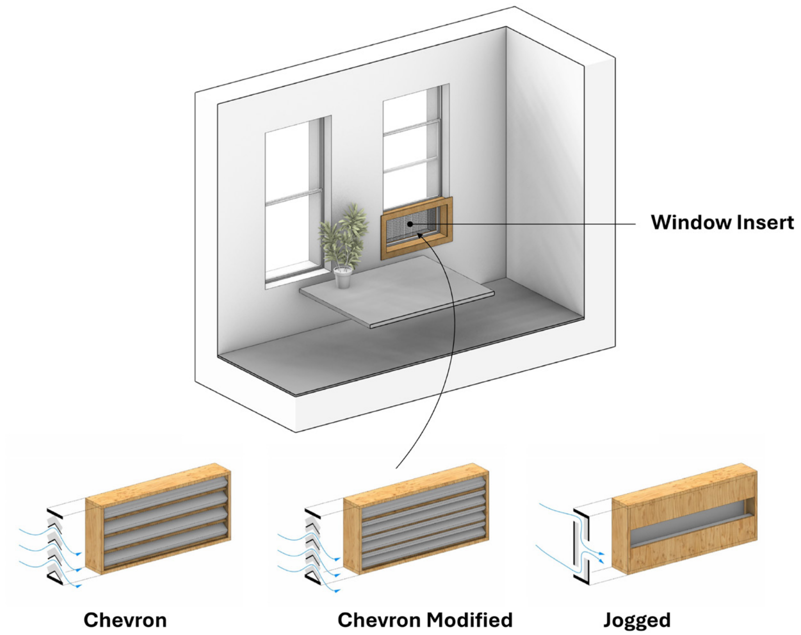


Figure 11. **Geometry of three different acoustic vents**

For the acoustic vent to function, there must be negative pressure between the indoor space and outdoors. Figure 12 shows three ways of creating this pressure. Our test as installed uses method 1, with a 395 cfm Vornado room air circulator placed in a window, exhausting outward. This configuration relies on ceiling fans to provide good mixing of air in the space, since there is no cross-ventilation. In spaces with existing mechanical exhaust available, that exhaust can be used to create the driving pressure and provide better cross-ventilation as shown in method 2 – but this will typically have lower flowrates than the 3 ach targeted for NV cooling. In a retrofit situation the most ideal configuration is method 3, using a larger exhaust specifically sized to provide fan-assisted natural ventilation. Figure 13 shows the window openings, opening insert, and acoustic inserts as tested.

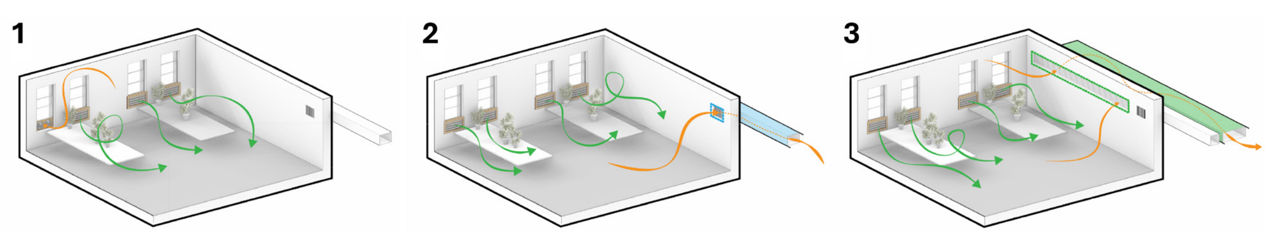
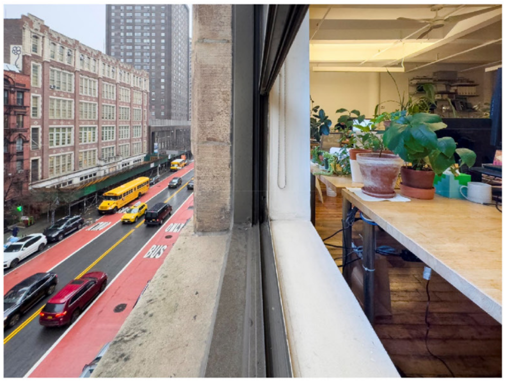
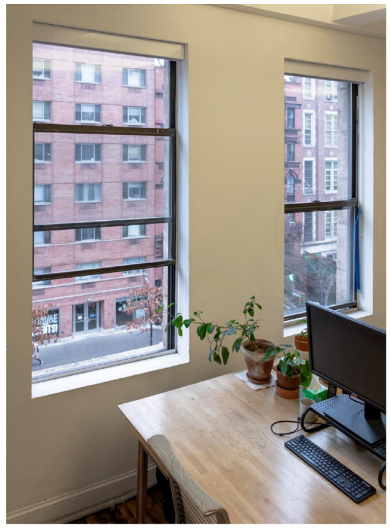
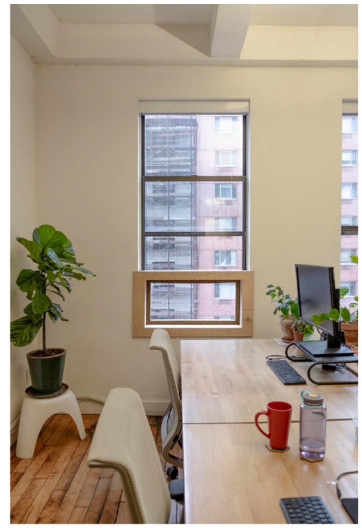
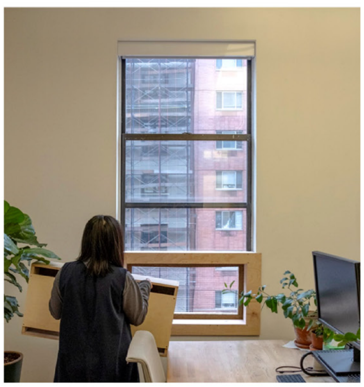
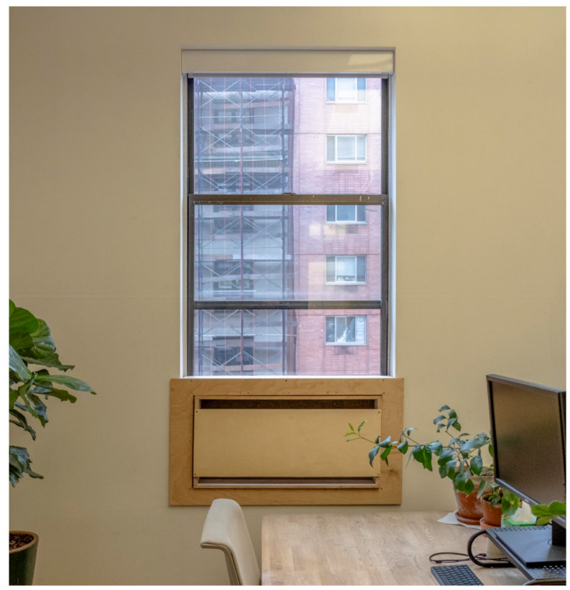
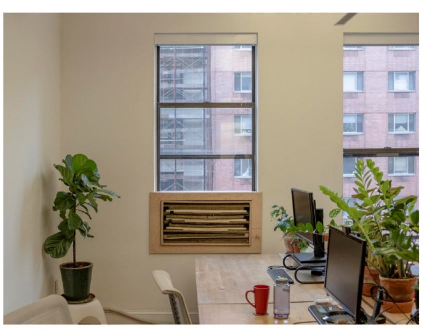
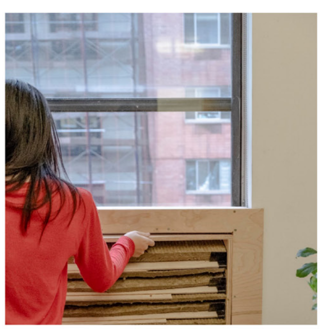


Figure 12. **Airflow paths (1) as installed, (2) using standard mechanical exhaust, and (3) using larger natural ventilation exhaust.**


Measurement Methodology

To compare the performance of our acoustic vents to products on the market, we collected sound transmission data and calculated several performance metrics. The experimental test setup was based on acoustic field measurement standards such as ASTM E966-18a, ASTM E90-99 and ISO 10140-2 (ASTM International 2018, ASTM International 1999, International Organization for Standardization 2010). These standards provide methods for measuring and calculating sound attenuation through building elements. Our data collection was similar to these standards but does not meet them; it is a simplified method performed on January 2 and 3, 2024 in the office.

Sound data was captured through two lapel microphones, one mounted on the exterior casing of the acoustic insert, the other mounted on a desk 3 feet away from the center of the acoustic insert. The microphones recorded the indoor and outdoor environments simultaneously to two separate audio channels with gain calibrated such that each microphone recorded matching input dB levels when placed next to each other. Audio recording was done with OBS Studio 29.1.3 and processed using Audacity 3.4.2.

Using the Audacity "Plot Spectrum" function that uses a Fast Fourier Transform (FFT) with a frequency resolution of 83 Hz, the recorded dB FS was approximately corrected to dB SPL using the lapel microphone's sensitivity of -28 dBV/Pa and the sampling rate of 44.1 kHz, 16-bit ADC. Measurements were averaged over 5 minutes. The RMS of sampled levels in each frequency bin were taken to arrive at 1/3 octave band sound power levels for indoors and outdoors.

Measurements were taken both with the exhaust fan off and on. We used a handheld hot-wire anemometer to measure the average air velocity at the room-side face of the acoustic insert, based on several sample points. The average air velocity multiplied times the free area was used to estimate the flowrate through the insert with the fan on.

Metrics

We calculated three metrics for the sound attenuation of each acoustic insert; all metrics first required calculating Sound Transmission Loss (STL). STL can be calculated several ways depending on the experimental setup. We used a simplified method which is often referenced in acoustic louver performance data sheets. The difference between the outside sound power (Po) and inside (Pi) yields the Free Field Noise Reduction (FFNR). FFNR – 6.18 yields the Sound Transmission Loss for each 1/3 octave band. STL is used as the basis for the calculation of STC, OITC, and Rw.

Sound Transmission Class (STC) is defined by reference contours found in E413 (ASTM International 2010). Technically, STC can only be calculated from test conditions that meet ASTM E90-99, which ours did not, but we applied the method of E413 to calculate STC based on our measurements. STC provides greater weighting to higher frequency bands to emphasize speech sound transmission attenuation.
Outdoor Indoor Transmission Class (OITC) is defined by ASTM E133-22. Technically, OITC can only be calculated from test conditions that meet ASTM E133-22, which ours did not, but we applied the method of E133 to calculate OITC based on our measurements. OITC is defined by frequency center bands from 80 - 4000 Hz. The metric assigns greater weight to lower frequency bands to emphasize the performance of sound transmission from road and traffic noise.

Weighted Sound Reduction Index (Rw) is defined by reference contours found in ISO 10140-2. Again, Rw can only be calculated from test conditions that meet ISO 10140-2, which ours did not, but we applied the method of 10140-2 based on our measurements. Rw is defined by frequency center bands from 100 - 3150 Hz. Rw and STC are generally analogous in their intent, but Rw values are usually one or two higher than STC. Many European and British products use the Weighted Sound Reduction Index (Rw).

Results

With the exhaust fan on, the velocity at each acoustic vent face was 1.3 – 1.6 m/s (260 – 320 fpm), corresponding to air flowrates of 260 – 320 cfm, meeting the target airflow of 167 cfm per vent. Although there is little airflow with the exhaust fan off, we took sound measurements with the exhaust fan off because the fan itself generates noise inside the space, interfering with the sound measurement. A permanent installation would aim to use method 2 or 3 shown in Figure 12, where an exhaust fan does not generate noise in the space. The flow of air through the insert should not significantly influence the acoustic performance of the insert.

Figure 14 shows the sound transmission loss with the fan off, while Figure 15 shows sound transmission loss with the fan on. The trends in both charts are similar, but the sound transmission loss is about 5 dB less with the fan on. This is a result of the fan noise which is included in the indoor sound measurement. The chevron modified design performs the best, providing the highest transmission loss at most frequencies, but is only slightly better than the jogged design across the lower frequency ranges that include most troublesome outdoor noise and human speech (less than 1600 Hz). The chevron modified design performs exceptionally well at high frequencies (1600 – 12800 Hz), but these are not as critical for outdoor sound attenuation.

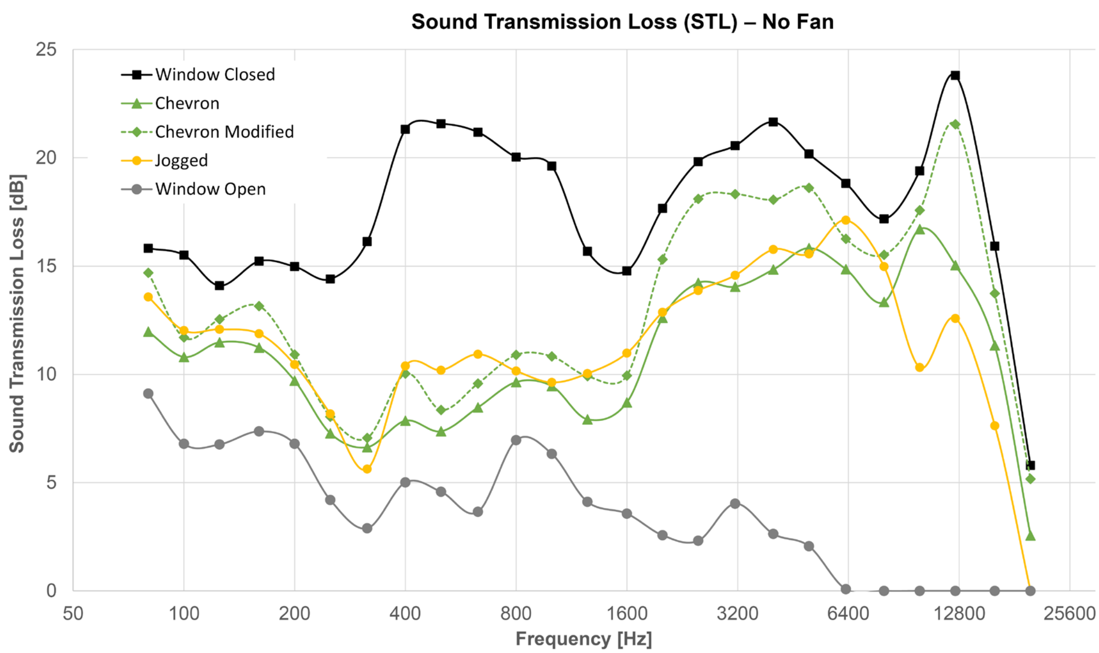


Figure 14. **Sound transmission loss for 1/3 octave bands of each design with fan OFF**

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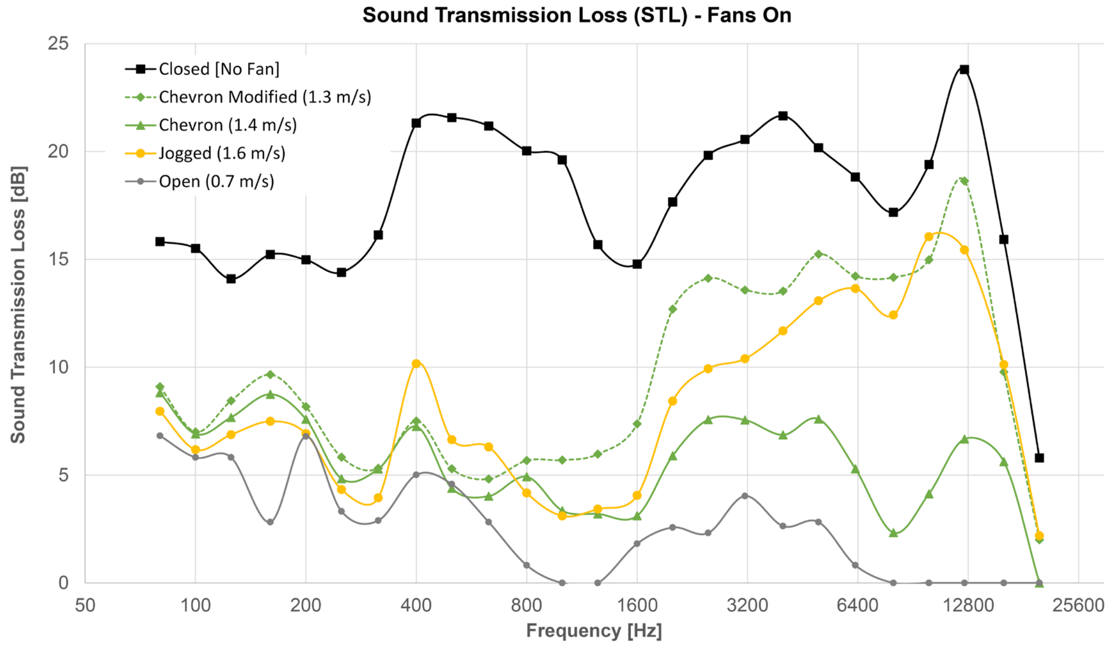


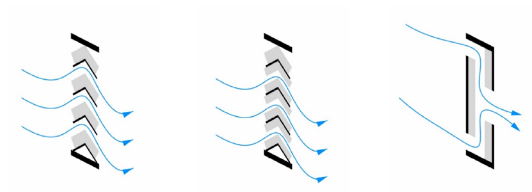
Figure 15. **Sound transmission loss for 1/3 octave bands of each design with fan ON**

Table 3 shows the sound attenuation metrics calculated for each insert, based on the STL data in Figures 14 and 15. Results are shown both with the fan on and off. Similar to STL, the figures with the fan on are generally 2-5 lower than with the fan off because of the interior fan noise. Here we focus on the results with the fan off, which is the preferred permanent application.

All three designs are effective in providing some sound attenuation, with all performance metrics significantly higher than the window open case (values of 10 – 17 vs. 4-10). No design can outperform the closed window, which yields values of 19-24. The chevron-modified design performs the best across all metrics, but the jogged design nearly matches its performance (and is equal for OITC).

Compared to the manufacturer products in Table 2 and Figure 8, the sound transmission loss in the critical lower frequencies (less than ~400 Hz) is similar at 7-10 dB, versus 4-5 dB for the open window. The calculated metrics STC, Rw, and OITC are also similar to other acoustic louvers or products designed for cooling ventilation. The performance is not as good as trickle vents and similar products designed for minimum ventilation only.

Table 3. **Calculated sound attenuation performance for each acoustic insert and open window over a single five minute period.**



	Window Closed (No Fan)	Chevron (No Fan / Fan)	Chevron Modified (No Fan / Fan)	Jogged (No Fan / Fan)	Window Open (No Fan / Fan)
Sound Transmission Class (STC)	19	10 / 5	12 / 8	11 / 6	4 / 2
Weighted Sound Reduction Index (Rw)	19	11 / 6	13 / 9	12 / 7	4 / 2
Outside Inside Transmission Class (OITC)	24	15 / 13	17 / 11	17 / 12	10 / 8

Observations

The results show that some acoustic benefit can be achieved from extremely simple AP-NV designs using readily available materials. Our qualitative impression during testing matched this result; although outside noise was clearly still audible with the inserts installed, it was noticeably dampened compared to an open window.

The other key impression was the loss of view when the insert is installed in the lower portion of the window. Occupants would be unlikely to install a permanently installed vent in this location completely in place of a window. In a retrofit installation like ours, we would prefer to install the louver at the top of the window. However, this would reduce daylight penetration depth into the space because the upper window is the key contributor to deep daylighting. Testing in this position was not possible because the upper sash of our windows is fixed. We are developing a second-generation prototype for our simple office installation. This will be intended for longer-term testing and aim to provide better views while maintaining the ventilation and acoustic performance.

In new construction or major renovations, acoustic elements should be placed next to or beneath the vision glazing to avoid this problem. This is the configuration typically seen in the case study projects presented.

Conclusions

Both precedent projects and market for manufactured products show there is already demand for AP-NV and it has been applied effectively. Climate and air quality conditions in New York and other North American cities can allow for extensive use of natural ventilation, but outdoor noise in urban areas if often a barrier to keeping windows open.

Our very simple prototype in New York shows that AP-NV can be provided using simple, readily available materials. The free area requirements for cooling with natural ventilation result in ventilation elements with large face areas which must be carefully integrated in a design. Design integration is easier in new construction or major renovations where façade openings are being modified; smaller-scope renovations must carefully consider impacts on daylight and views. The most effective applications will include a driving force creating negative pressure that does not generate noise within the space served. A co-benefit is that most AP-NV strategies also enhance security for NV in unoccupied spaces.

The first applications of acoustic NV in North America will likely be custom designs or off-the-shelf acoustic louvers integrated into a custom application. With time, we encourage manufacturers to make small modifications to existing products and market them specifically for acoustically protected natural ventilation.

Postscript

Since completion of this research effort we have designed, constructed, and installed a second prototype in all four windows in our Manhattan office. The details are beyond the scope of this paper, but the second version improves on the first prototype especially by (1) using a flatter, projecting geometry which avoids blocking view, (2) using a new baffle design that maximizes free area for flow, and (3) incorporating small DC computer fans to provide the necessary pressure difference.
We will continue to use these in our daily operations over the coming months. Figure 16 shows the installed second prototype.

Figure 16. **Second prototype installed for long-term testing at Transsolar New York**

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