Effectiveness Is Not a Constant: Operating-Point Selection for Energy Recovery Ventilators

Architecture, Computational Methods, and a Modelled Efficiency Case from MileSoft ERV Selection Software

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Working paper — Version 1.0 — 22 August 2026
Permanent link: https://milesoft.net/research/products/erv

Abstract

Energy recovery ventilators are specified against a single effectiveness figure and operate across a year of conditions in which that figure does not hold. Effectiveness varies with airflow ratio, with the temperature difference between the streams, and — for total-energy devices — with humidity. A unit selected to satisfy a summer design condition may recover materially less across the annual profile that determines its actual energy contribution, and the gap is invisible in the number that was specified.

This paper presents the architecture and computational methods of MileSoft ERV Selection Software, which treats effectiveness as a function of operating point rather than as a device constant. The tool evaluates sensible, latent and total effectiveness from the fresh- and return-air states, computes the full leaving state on both streams, reports supply- and exhaust-side pressure drops separately, and sizes both fans — so the parasitic cost of recovery is stated alongside the recovery itself.

We state the three effectiveness definitions, the leaving-state solution that follows from them, the fan-power penalty that determines whether recovery is a net gain, and the frost-control energy debit that a cold-climate selection must carry. The work is anchored in AHRI Standard 1060 and ANSI/ASHRAE Standard 84 for the rating and test basis, and in ANSI/ASHRAE/IES Standard 90.1, whose energy-recovery provisions set the enthalpy recovery ratio a compliant selection must reach.

This module appears in no published deployment case study. Section 5 therefore reports a modelled scenario with its assumptions printed rather than a field result, and makes no deployment claim. We close with a capability reference framework for energy-recovery selection tooling.

Keywords: ERV selection software; Energy recovery ventilator; AHRI 1060; ASHRAE 84; Sensible effectiveness; Latent effectiveness; Enthalpy recovery ratio; ASHRAE 90.1 energy recovery; Frost control; Wheel versus plate exchanger; Exhaust air transfer ratio; Specific fan power penalty

1 Introduction

Energy recovery has moved from an optional efficiency measure to a code obligation across much of the commercial building stock. ANSI/ASHRAE/IES Standard 90.1 requires energy-recovery systems above defined thresholds to reach a minimum enthalpy recovery ratio — 50% at cooling conditions and 60% at heating conditions where both modes apply. Once a device is required rather than chosen, the question shifts from whether to recover to what the recovery is actually worth.

That question is harder than the specification implies, because the number in the specification is a rated point and the device operates across a year. Effectiveness varies with the ratio of the two airflows, with the driving temperature difference, and — for total-energy devices — with the humidity difference. A unit that satisfies a summer design condition can recover materially less across the annual profile that determines its energy contribution.

This paper describes a tool built to treat effectiveness as a function of operating point rather than as a device constant, and to state the parasitic cost of recovery alongside the recovery itself. The second half matters as much as the first: a device that recovers thermal energy while consuming more fan power than it saves is a net loss that a single-figure specification cannot detect.

1.1 Four sizing problems, not one

A defensible energy-recovery selection resolves four questions that a single effectiveness figure conflates. What is the sensible recovery at the design condition. What is the latent recovery, which for a total-energy device is a separate transport mechanism with its own effectiveness. What pressure drop does the device impose on each stream, and what fan power does that cost. And what happens in the hours when the device cannot run as specified — most often because of frost.

Treating these as one problem is what produces the familiar disappointment: a device that meets its rated effectiveness on the test stand and returns less than projected in the building, with the shortfall attributed vaguely to operating conditions.

> Effectiveness is a ratio evaluated at a state. Quoting it without the state is like quoting a chiller's efficiency without saying at what load.

1.2 Contributions

1. An effectiveness model evaluated at the project's own fresh- and return-air states and airflow ratio, reporting sensible, latent and total effectiveness separately as AHRI 1060 rates them.

2. A leaving-state solution that returns the full psychrometric condition of both streams rather than a single recovered-energy figure.
3. Explicit reporting of supply- and exhaust-side pressure drops and both fan powers, so the net thermal gain can be computed rather than assumed.
4. An eight-dimension capability reference framework for energy-recovery selection tooling.

2 Background and Related Work

Three regimes govern an energy-recovery selection: the rating basis that defines what an effectiveness figure means, the test method behind it, and the energy code that makes reaching a threshold obligatory.

2.1 The rating basis

AHRI Standard 1060, with Standard 1061 as its SI counterpart, establishes definitions, test requirements, rating requirements, minimum data requirements for published ratings, marking and nameplate data, and conformance conditions for air-to-air exchangers used in energy recovery ventilation equipment. The certification programme covers heat pipe, plate and rotary exchangers rated at or above 50 scfm and up to 5,000 scfm at standard rating conditions.

Two provisions matter directly to selection. First, effectiveness is rated separately for sensible and total energy transfer, so a total-energy device carries two distinct figures that behave differently across operating conditions. Second, supply- and exhaust-side pressure drops are reported separately rather than combined — which exists precisely so that the fan power on each stream can be established rather than estimated.

ANSI/ASHRAE Standard 84 supplies the test method behind these ratings. It specifies test conditions, required data, the uncertainty analysis to be performed, the calculations, and reporting procedures, and it covers the full range of device types — regenerative wheels, heat pipes, thermosiphons, run-around loops and fixed-plate exchangers — in both laboratory and field tests where the required uncertainty can be achieved.

2.2 The code threshold

Standard 90.1's energy-recovery provisions define the enthalpy recovery ratio as the change in enthalpy of the outdoor air supply divided by the difference between the outdoor air and entering exhaust air enthalpies, expressed as a percentage, and require a minimum of 50% at cooling conditions and 60% at heating conditions where both are required.

The definition rewards close reading because it is an enthalpy ratio, not a temperature ratio. A sensible-only device cannot reach it in a humid climate however good its temperature effectiveness is, because the denominator contains a latent term the device does not address. This is the code provision behind the wheel-versus-plate decision described in Section 4.4.

2.3 Failure modes of single-figure selection

- Rated effectiveness treated as annual. The design-point figure is applied across the year, ignoring that effectiveness rises at reduced airflow and varies with the driving difference.
- Sensible figure used against an enthalpy requirement. A temperature effectiveness is quoted where Standard 90.1 asks for an enthalpy recovery ratio, which a sensible-only device cannot satisfy in a humid climate.
- Fan power omitted. Pressure drop on the two streams is not carried into a fan-power calculation, so a device with high effectiveness and high resistance appears strictly better than a moderate one.
- Frost ignored. Cold-climate hours in which frost control is active — and recovery reduced or suspended — are absent from the annual estimate.
- Exhaust air transfer unconsidered. For rotary devices, carryover and purge behaviour is not evaluated, which matters where the exhaust stream is contaminated.

3 System Overview

The module is a psychrometric effectiveness engine wrapped in a project workflow: secure sign-in to a shared workspace, a dashboard of projects, capture of project and client data, unit selection against the zone's specification, and an exportable selection report.

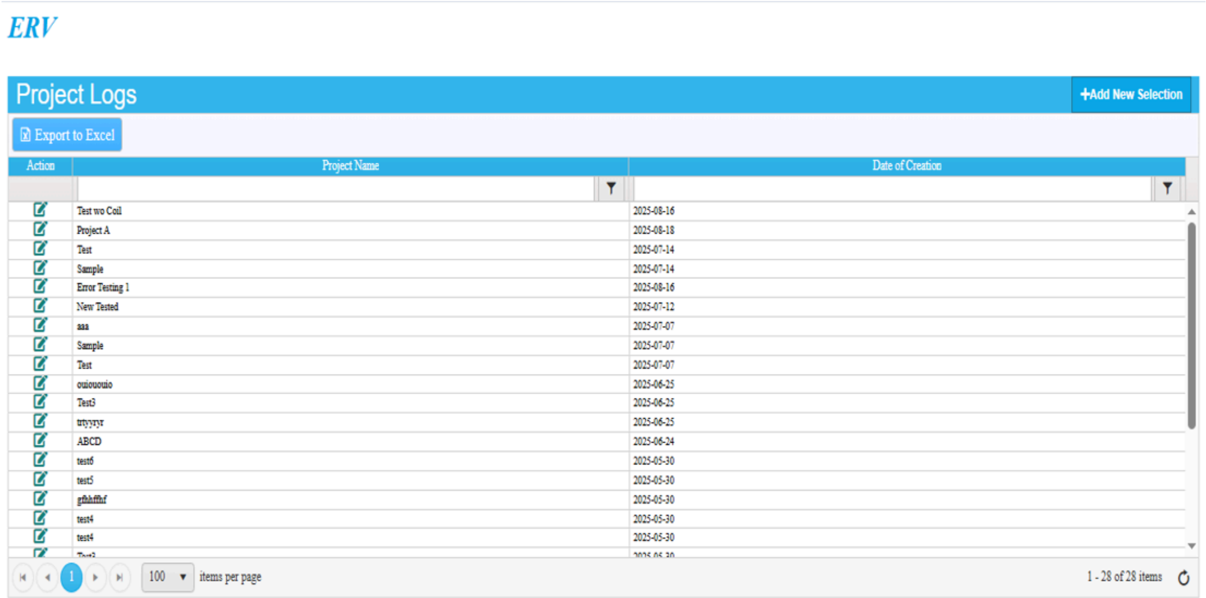

Figure 1. The project dashboard. Recovery devices are selected against a project's ventilation requirement rather than in isolation, so the tool's top-level object is a project rather than a device.

3.1 What the engine takes in

The selection is driven by the two air states and the two flows. Fresh air enters at an outdoor condition given by the project's location and design assumption; return air enters at the building's condition. Each stream has its own volume flow and its own external static pressure, and the ratio between the flows is itself an input rather than an assumption of balance.

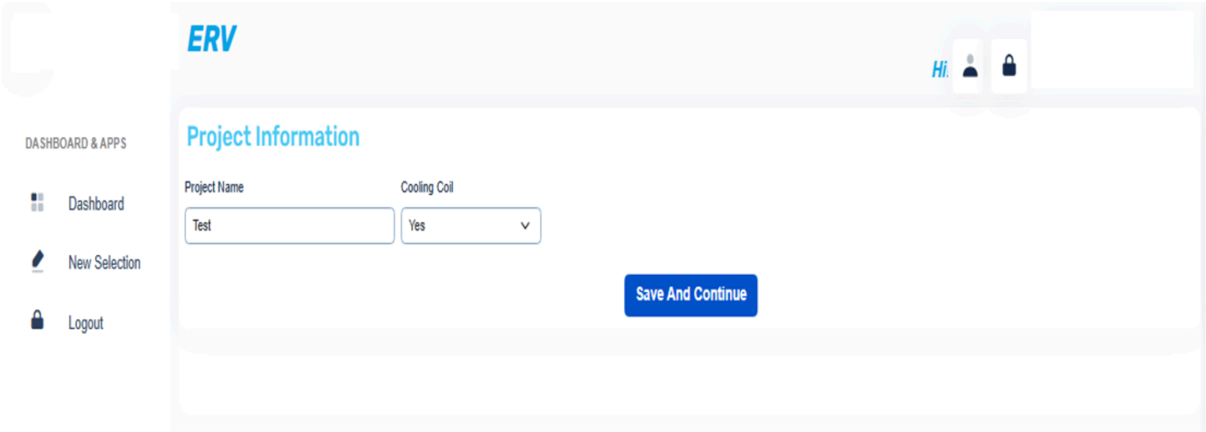

Figure 2. Project information. Location determines the outdoor design condition, which is the input that most strongly moves the effectiveness the device will actually deliver — and the input most often carried over unchanged from a previous project.

Treating the airflow ratio as an input rather than assuming balanced flow is not a refinement. Unbalanced flow is the normal case in buildings with exhaust from toilets and kitchens, and effectiveness is a function of the ratio: a device rated at balanced flow will behave differently when the exhaust stream is smaller than the supply.

3.2 What the engine returns

The output is not a single recovered-energy figure but the complete leaving state on both streams — dry-bulb and wet-bulb temperature, relative and absolute humidity, and enthalpy — together with the three effectiveness values, the supply- and exhaust-side pressure drops reported separately per AHRI 1060, and the sizing of both fans.

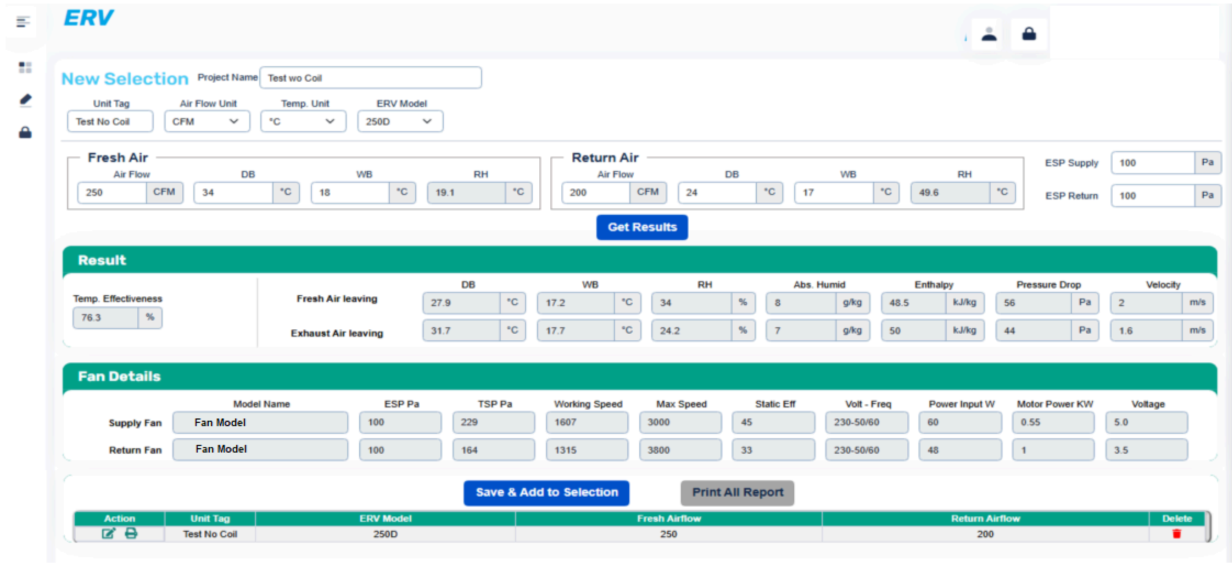

Figure 3. Unit selection. Returning the full leaving state rather than a recovered-energy total is what allows the downstream coil to be sized correctly — the recovery device changes the air the coil will see, and a single kilowatt figure does not describe that change.

The leaving state matters beyond the recovery calculation. A recovery device changes the condition presented to whatever follows it, so an AHU coil downstream must be rated at the post-recovery state. Reporting only the energy recovered leaves the next selection with nothing to work from.

ENERGY RECOVERY VENTILATOR TECHNICAL REPORT

GENERAL

ERV Model	250D	Inner Skin thickness	0.5mm GI	Cooling Coil	N/A
Casing Type	Double Skin	Outer Skin thickness	0.7mm Precoated Steel	Fluid inlet (°C)	N/A
Insulation Thickness	42mm	Insulation Material	PIR insulation (Polyisocyanurate insulation)	Fluid outlet (°C)	N/A
Supply Airflow	250 (CFM)	Supply Fan ESP	100 (Pa)	Unit Dimensions (LXWXH) mm (Without Coil box)	
Return Airflow	200 (CFM)	Return Fan ESP	100 (Pa)	Unit Dimensions (LXWXH) mm (External Coil box)	Consult Factory

FILTER SECTION

Prefilter Grade	G4	Bag Filter Grade	F7	Material	Synthetic	Material	Synthetic
Prefilter Depth	48mm	Bag Filter Depth	390mm	Prefilter PD(Pa)	25	Bag Filter PD(Pa)	48

HEAT RECOVERY WHEEL SECTION

	DB (°C)	WB (°C)	RH %	Absl. Humidity (g/Kg)	Enthalpy (kJ/kg)	Pressure Drop (Pa)	Velocity (m/s)
Fresh Air Condition	34.0	18.0	19.1				
Return Air Condition	24.0	17.0	49.6				
Supply Air Condition	27.9	17.2	34	8	48.5	56	2.0
Exhaust Air Condition	31.7	17.7	24.2	7	50	44	1.6
Temp. Effectiveness	76.3	Motor Nominal Power (kw) : 0.04					

COOLING COIL (EXTERNAL COIL BOX)

Cooling Coil Type	CW	Total Capacity (Kw)	2.18	Evaporating Temp (°C)	N/A
Coil Tube Dia	3/8	Sens. Capacity (Kw)	2.01	Refrigerant	N/A
Number of Rows	3	On Coil DB (°C)	27.9	Chilled Water Fluid in (°C)	7.0
Fin Spacing mm	1.81	On Coil WB (°C)	17.2	Chilled Water Fluid out (°C)	12.0
Coil Face Velocity	1.24	Off Coil DB (°C)	14.0	Water Flow Rate (Lps)	0.1
Coil Internal Volume	1.06	Off Coil WB(°C)	11.6	Water Pressure Drop (Kpa)	13.74
Coil Frame	Galvanised	Fin Material	Aluminum	Air Pressure Drop (Pa)	37
Tube Material	Copper	Inlet Connection Size	1/2"	Outlet Connection Size	1/2"
Coil Code	CW-3/8th 1 in Equat. -CW-AHRI-1.8-250-381.0-3R-2-S-Cu 0.30/Al 0.11				

FAN SECTION

	Fan Model	ESP (Pa)	ISP (Pa)	TSP (Pa)	Control Voltage		
Supply Fan	SR-FS-P-250-0.3	100	166	266	5.4		
Return Fan	SR-FS-P-250-0.7	100	64	164	3.5		
	Design Speed (RPM)	Max Speed (RPM)	Static Eff (%)	Total Eff (%)	Power Input (W)	Motor Nominal Power (KW)	Motor Nominal Current (Amps)
Supply Fan	1722	3000	44	45	71	0.55	3.5
Return Fan	1315	3800	33	33	48	1	4.4
Power Supply	220V/1Ph/50-60Hz						

Figure 4. The selection report. Because it carries both effectiveness figures and both pressure drops, a reviewer can verify the enthalpy recovery ratio against the Standard 90.1 threshold without returning to the vendor for data.

4 Computational Methods

Notation is collected in Appendix A; worked numerical examples in Appendix B.

4.1 The three effectiveness definitions

Effectiveness is the ratio of the energy actually transferred to the maximum that could be transferred between the two streams. AHRI 1060 and ASHRAE 84 define it separately for the sensible, latent and total cases, each normalised by the smaller of the two mass flows.

$$eps(sensible) = [\, t(1) - t(2) \,] / [\, t(1) - t(3) \,],\ eps(latent) = [\, w(1) - w(2) \,] / [\, w(1) - w(3) \,],\ eps(total) = [\, h(1) - h(2) \,] / [\, h(1) - h(3) \,] \qquad \text{(eff)}$$

where state 1 is entering supply (outdoor) air, state 2 is leaving supply air, and state 3 is entering exhaust (return) air; t is dry-bulb temperature, w humidity ratio and h specific enthalpy. Each ratio is evaluated at the minimum mass flow of the two streams.

The three are not interchangeable and they do not move together. A fixed-plate exchanger has a sensible effectiveness and a latent effectiveness near zero, so its total effectiveness is dominated by whichever term the climate makes larger. A total-energy wheel transfers moisture as well, so its latent and total figures are substantial — and it is the total figure that Standard 90.1's enthalpy recovery ratio corresponds to.

This is the wheel-versus-plate decision in one line: in a humid climate a plate exchanger with excellent sensible effectiveness can still fail an enthalpy recovery requirement it was never able to address.

4.2 Solving the leaving state

Given the entering states and the effectiveness values, the leaving supply state follows by rearrangement, and the leaving exhaust state follows from an energy balance across the device.

$$t(2) = t(1) - eps(sensible) \times [\, t(1) - t(3) \,],\ w(2) = w(1) - eps(latent) \times [\, w(1) - w(3) \,] \qquad \text{(leaving)}$$

the leaving supply condition is fully determined by dry-bulb temperature and humidity ratio; wet-bulb, relative humidity and enthalpy follow from the psychrometric relations at the local barometric pressure.

Solving both properties rather than temperature alone is what makes the output usable downstream. A recovery device that pre-cools outdoor air also changes its moisture content, and a coil sized against the pre-recovery humidity will be wrong in its latent duty for exactly the reasons set out in the companion paper on terminal units.

4.3 The parasitic penalty

Recovery is a net gain only if the thermal energy recovered exceeds the additional fan energy required to push both streams through the device. AHRI 1060's separate reporting of supply- and exhaust-side pressure drops exists to make this computable.

$$Q(net) = m(min) \times eps(total) \times [\, h(1) - h(3) \,] - [\, V(supply) \times dP(supply) / eta(supply) + V(exhaust) \times dP(exhaust) / eta(exhaust) \,] \qquad \text{(netgain)}$$

the first term is thermal energy recovered and the second the electrical power consumed pushing both streams through the exchanger. The two are not in the same currency — one is thermal, one electrical — so a fair comparison converts the thermal term by the plant's coefficient of performance before subtracting.

The distinction between thermal and electrical energy is where naive comparisons go wrong. Recovering 10 kW of thermal energy that would otherwise have been provided by a chiller with a coefficient of performance of 4 saves 2.5 kW of electricity. If the recovery device costs 1.5 kW of additional fan power, the net saving is 1.0 kW, not 8.5 kW.

4.4 Frost control and available hours

In cold climates the exhaust stream's moisture condenses and freezes on the exchanger when the supply-side surface falls below freezing. Every mitigation carries a cost. Preheating the incoming air consumes energy directly. Bypassing part of the supply stream reduces recovery for the duration. Recirculation and wheel-speed modulation reduce effectiveness rather than suspending it.

$$E(annual) = SUM \text{ over bins } b \text{ of } [\, hours(b) \times Q(\text{recovered at } b) \times availability(b) \,] - E(\text{frost control}) \qquad \text{(frost)}$$

where availability at bin b is the fraction of those hours during which recovery runs unimpaired, and E(frost) the energy consumed by the control strategy. Both terms are zero in a temperate climate and material in a cold one, which is why an annual estimate cannot be a single design-point figure scaled by operating hours.

The practical consequence for selection is that the device with the highest rated effectiveness is not necessarily the best in a cold climate. A high-effectiveness wheel frosts sooner than a moderate one, because it drives the supply-side surface temperature lower. The comparison must be made on delivered annual energy, not on the rating.

5 A Modelled Efficiency Case

> This module appears in no published deployment case study. There is therefore no field result to report, and none is claimed. What follows is a modelled scenario with its assumptions printed, and should be read as such.

5.1 What the product's own record states

The published record for this module is qualitative. It states that the software supports HVAC manufacturers in designing energy-efficient ventilation units compliant with ASHRAE, AHRI and EUROVENT standards, that unit recommendations follow automatically from design specifications, and that selection reports export in one click. No quantitative outcome is published for the module.

That absence is worth stating rather than filling. Several of the other modules in this series carry published performance figures; this one does not, and inventing a plausible number would be the easiest and least defensible way to make this section resemble the others.

5.2 Modelled engineer-hour recovery

Table 1. Published model parameters and the default-case result. Every input is adjustable; these are the published defaults, and the result is a modelled estimate rather than a measurement.

Parameter	Default
Manual selection time	45 minutes
Selection time in MileSoft	8 minutes
Selections per month	30
Engineer-hours released per year	222

The 45-minute manual baseline is the interesting parameter. An energy-recovery selection done properly requires solving the psychrometric leaving state on two streams and checking the enthalpy recovery ratio against a code threshold; done from a manufacturer's table it requires reading one number. The model's baseline sits closer to the second, so — as with the chiller module — it compares an incomplete manual method against a complete automated one.

5.3 What would constitute evidence

For completeness, the measurement that would substantiate this paper's argument is stated here rather than left implicit. It is a comparison, on an instrumented installation, between annual recovered energy predicted from a single rated effectiveness figure, annual recovered energy predicted from an operating-point model, and metered performance.

No such comparison is published for this module. The paper's claims about operating-point variation rest on the rating standards' own definitions — which establish that effectiveness is a ratio evaluated at a state — rather than on measured deviation between the two prediction methods.

6 Discussion

6.1 The enthalpy ratio is the provision that decides device type

Much of the wheel-versus-plate debate is conducted as a general comparison of technologies — cross-contamination risk, maintenance, moving parts. Standard 90.1's energy-recovery provision reframes it as arithmetic. The requirement is expressed as an enthalpy recovery ratio, and enthalpy includes a latent term.

In a dry climate the latent term is small, the enthalpy ratio approaches the temperature ratio, and a fixed-plate device can satisfy it. In a humid climate the latent term dominates the enthalpy difference, and a sensible-only device cannot reach the threshold at any temperature effectiveness. The climate, not the preference, decides.

6.2 Recovery is not free, and the units are not the same

The most common error in evaluating recovery is comparing recovered thermal energy directly against consumed electrical energy. They are not commensurable. Thermal energy that would have been supplied by a chiller at a coefficient of performance of four costs a quarter of its magnitude in electricity; fan power is electricity outright.

Carrying this conversion explicitly changes conclusions in the marginal cases that matter. A device with high effectiveness and high pressure drop can be a net loss on a mild-climate project with a high-efficiency chiller — which is exactly the situation in which a single-figure comparison would recommend it most confidently.

6.3 A capability reference framework for energy-recovery selection

Table 2. Capability reference framework. Each dimension is answerable by demonstration against a running system.

Dimension	Question the tool must answer by demonstration
D1 Operating-point effectiveness	Change the airflow ratio. Does the reported effectiveness move, or is it a device constant?
D2 Three ratios	Are sensible, latent and total effectiveness reported separately, as AHRI 1060 rates them?
D3 Leaving state	Does the output give the full psychrometric state of both streams, or only recovered energy?
D4 Separate pressure drops	Are supply- and exhaust-side pressure drops reported separately, and both fans sized?
D5 Net gain	Is thermal recovery converted by plant coefficient of performance before fan power is subtracted?
D6 Code check	Does the tool evaluate the enthalpy recovery ratio against the Standard 90.1 threshold, not a temperature ratio?
D7 Frost accounting	In a cold-climate project, does the annual estimate carry frost-control energy and reduced availability?
D8 Downstream handoff	Can the post-recovery state be passed to a coil selection, or must it be re-entered by hand?

D1 is the fastest discriminator. Change the airflow ratio and watch the effectiveness figure. If it does not move, the tool is quoting a nameplate.

6.4 Generalisability

The effectiveness formulation generalises to any air-to-air exchanger within the ASHRAE 84 scope — wheels, plates, heat pipes, thermosiphons and run-around loops — because the definitions are device-independent. The frost treatment is climate-specific and irrelevant in warm regions. The net-gain argument applies wherever recovery imposes pressure drop, which is everywhere, but its sign depends on local electricity price and plant efficiency and must be evaluated per project.

7 Threats to Validity and Limitations

1. No field evidence exists for this module. It appears in no published case study, so nothing in this paper is supported by a deployment result. This is the most significant limitation and it is not mitigated elsewhere in the text.
2. The core argument rests on definitions, not measurement. That effectiveness varies with operating point follows from the rating standards' own formulation. How much a single-figure prediction deviates from

metered annual performance is not established here.

3. Modelled ROI is not measurement. The 45-minute and 8-minute selection times are vendor estimates, and as Section 5.2 notes the manual baseline appears to describe a table lookup rather than a complete psychrometric selection.
4. Frost modelling is bin-based. Availability is treated as a per-bin fraction rather than simulated hour by hour, which is adequate for comparison between devices and weaker as an absolute annual prediction.
5. Exhaust air transfer is not quantified here. Carryover and purge behaviour in rotary devices is named as a selection consideration but no transfer ratio model is presented.
6. No cost data. Device, installation and maintenance costs are not reported, so no return-on-investment conclusion is drawn.

A reader comparing this paper against the others in the series should weight it accordingly. Its architecture and methods are stated to the same standard; its evidence base is materially thinner.

8 Future Work

- Instrumented validation. Metering an installation and comparing measured annual recovery against both a single-figure and an operating-point prediction is the missing evidence, and would settle the paper's central claim.
- Hour-by-hour frost simulation. Replacing bin-based availability with an hourly model would turn the frost debit from a comparative term into an absolute annual figure.
- Exhaust air transfer ratio. Modelling carryover and purge for rotary devices would let contamination-sensitive applications be evaluated within the same selection rather than as a separate review.
- Coupling to downstream coil selection. The post-recovery state is computed but is not yet handed automatically to an AHU or FCU selection, so the benefit of solving both properties is currently realised by hand.
- Bin-weighted reporting as default. Reporting annual recovered energy against a bin profile, rather than effectiveness at design, would align the output with how the device is actually judged.

9 Conclusion

Effectiveness is a ratio evaluated at a state, and an energy recovery ventilator is specified with one number and operated across a year of states. This paper has described a tool that treats effectiveness as a function of operating point — computing sensible, latent and total ratios separately from the project's own air states and airflow ratio, returning the full leaving condition on both streams, and reporting the fan-power penalty alongside the thermal recovery so that net gain can be established rather than assumed.

The regulatory context makes this more than a refinement. Standard 90.1 expresses its energy-recovery requirement as an enthalpy recovery ratio, which contains a latent term that a sensible-only device cannot address — so in a humid climate the code provision, not a preference, decides the device type.

Unlike the other papers in this series, this one reports no field evidence, because none is published for this module. Its claims rest on the rating standards' definitions and on a modelled scenario whose assumptions are printed. The capability reference framework of Section 6.3 is offered as the durable contribution, and its first question takes a few seconds to ask: change the airflow ratio, and see whether the effectiveness figure moves.

Appendix A Nomenclature

Table 3. Symbols and abbreviations used in this paper.

Symbol / term	Meaning
state 1	Entering supply air — the outdoor condition
state 2	Leaving supply air — the condition delivered downstream
state 3	Entering exhaust air — the building's return condition
t	Dry-bulb temperature
w	Humidity ratio, mass of water vapour per unit mass of dry air
h	Specific enthalpy of moist air
eps(sensible)	Sensible effectiveness — temperature ratio
eps(latent)	Latent effectiveness — humidity ratio
eps(total)	Total effectiveness — enthalpy ratio
m(min)	The smaller of the two stream mass flows
V(supply), V(exhaust)	Volume flow on the supply and exhaust streams
dP(supply), dP(exhaust)	Pressure drop across the device on each stream, reported separately per AHRI 1060
eta(supply), eta(exhaust)	Combined fan, drive and motor efficiency on each stream
Q(net)	Net gain — thermal recovery less the electrical cost of achieving it
availability(b)	Fraction of hours in bin b during which recovery runs unimpaired
E(frost)	Annual energy consumed by the frost-control strategy
ERV	Energy recovery ventilator — a total-energy device
HRV	Heat recovery ventilator — a sensible-only device

Appendix B Worked Numerical Examples

Appendix B.1 Solving the leaving state at a summer design condition

Outdoor air enters at 38 degrees Celsius dry bulb with a humidity ratio of 0.0182 kg/kg and an enthalpy of about 85.0 kJ/kg. Return air enters at 24 degrees with a humidity ratio of 0.0093 kg/kg and an enthalpy of about 47.8 kJ/kg. Flows are balanced. The device is a total-energy wheel with a sensible effectiveness of 0.75 and a latent effectiveness of 0.68.

Applying Equation (leaving): t(2) = 38 — 0.75 x (38 — 24) = 38 — 10.5 = 27.5 degrees. w(2) = 0.0182 — 0.68 x (0.0182 — 0.0093) = 0.0182 — 0.00605 = 0.01215 kg/kg. The leaving supply enthalpy at that state is about 58.6 kJ/kg.

Applying Equation (eff) for the total ratio: eps(total) = (85.0 — 58.6) / (85.0 — 47.8) = 26.4 / 37.2 = 0.710. The enthalpy recovery ratio is therefore 71%, comfortably above the 50% cooling threshold. A sensible-only device with the same 0.75 temperature effectiveness would leave the supply air at 27.5 degrees but at the original 0.0182 kg/kg, giving an enthalpy of about 74.2 kJ/kg and a total ratio of (85.0 — 74.2) / 37.2 = 0.290 — which fails the threshold.

> Two devices with identical temperature effectiveness, 71% and 29% on the code's own measure. This is the wheel-versus-plate decision, and it is decided by the latent term rather than by preference.

Appendix B.2 Whether the recovery is worth its fan power

Take the same device at 2.0 m3/s on each stream, with an air density of 1.2 kg/m3 so each mass flow is 2.4 kg/s. From the enthalpy figures above, thermal recovery is 2.4 x (85.0 — 58.6) = 63.4 kW.

The device imposes 220 Pa on the supply stream and 200 Pa on the exhaust, at a combined fan efficiency of 0.60 on each. Applying the second term of Equation (netgain): supply fan power is 2.0 x 220 / 0.60 = 733 W; exhaust fan power is 2.0 x 200 / 0.60 = 667 W. Total parasitic power is 1.40 kW.

The two terms are not in the same currency. Converting the thermal recovery at a plant coefficient of performance of 4.0 gives an avoided electrical demand of 63.4 / 4 = 15.85 kW. Net saving is 15.85 — 1.40 = 14.45 kW — a strong result.

Now change two assumptions. A device with 480 Pa and 450 Pa pressure drops at the same effectiveness costs 2.0 x 480 / 0.60 + 2.0 x 450 / 0.60 = 1,600 + 1,500 = 3.10 kW. On a mild-climate project where the enthalpy difference is a third as large, thermal recovery falls to about 21.1 kW, avoided electrical demand to 5.28 kW, and the net saving to 2.18 kW. The high-pressure device has consumed more than half the benefit — and on a milder day still it would consume all of it.

Appendix B.3 The published engineer-hour model

MileSoft's published model assumes a manual ERV selection takes about 45 minutes against about 8 minutes in the tool, at 30 selections per month.

Time saved per selection is (45 — 8) / 60 = 0.6167 h. Annual selections are 30 x 12 = 360. Engineer-hours released are 0.6167 x 360 = 222 h per year.

This is the smallest of the six HVAC module models, which is consistent with energy recovery being a lower-volume selection than terminal units or air handlers. It carries the same caveat as the others and one specific to this module: a manual selection that solved the leaving state on both streams, as Appendix B.1

does, would take considerably longer than 45 minutes, so the modelled saving understates the difference between doing the work properly by hand and doing it in the tool.

Data provenance

Every quantitative claim in this paper resolves to one of the entries below. Figures marked as modelled estimates are not deployment measurements; their assumptions are stated.

Metric	Reported value	Provenance
Minimum enthalpy recovery ratio required by ASHRAE 90.1 energy-recovery provisions	50% cooling, 60% heating	**Defined by ANSI/ASHRAE/IES Standard 90.1** Applies where both modes are required; the threshold is what converts energy recovery from an option into a code obligation.
Engineer-hours released per year, ERV selection	222 h/yr (modelled)	**Modelled estimate** A manual ERV selection takes ~45 min; ~8 min in MileSoft; 30 selections per month, 360 per year; Model and defaults published in src/data/roiModels.ts

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