The Installation Is Part of the Machine: Line-Set Penalty, Multi-Circuit Balance, and Defrost in Direct-Expansion Selection

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

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Abstract

A direct-expansion system is rated as a matched pair on a test stand and installed as a refrigerant circuit through a building. Between those two states sit the line set, the vertical separation between indoor and outdoor units, the actual ambient the condenser will see, and — in multi-circuit equipment — the interaction between circuits that share a coil face. Catalogue capacity tables describe the test stand. The installation degrades capacity and efficiency by an amount the table does not carry, reported in the product's own record as 15-25% in many real-world installations.

This paper presents the architecture and computational methods of MileSoft DX Selection Software, built on the premise that the installation is part of the machine and must therefore be part of the selection. The tool matches required total and sensible capacity at the project's entering and ambient conditions, applies the line-set penalty from length and vertical rise, balances multi-circuit equipment, and carries heat-pump defrost across the winter envelope rather than quoting a single heating capacity.

We state the capacity-matching method against the project's own conditions, the line-set correction, the multi-circuit balance condition, and the defrost-adjusted seasonal heating output. The work is anchored in AHRI Standard 210/240 for unitary equipment below 65,000 Btu/h and AHRI Standard 340/360 for commercial equipment from 65,000 to 760,000 Btu/h, whose different efficiency metrics make capacities either side of that boundary non-comparable.

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

Keywords: DX selection software; Direct expansion unit selection; Line set length penalty; AHRI 210/240 SEER2; AHRI 340/360 IEER; Multi-circuit balance; Heat pump defrost; Sensible heat ratio; Refrigerant charge; Packaged rooftop selection; Variable refrigerant flow; Condenser ambient derating

1 Introduction

A catalogue capacity for a direct-expansion system describes a matched indoor and outdoor unit connected by a short, level refrigerant line at a defined ambient. Almost no installation resembles that. The indoor unit sits several floors below or above the condenser, connected by a line set with bends and rise, and the condenser faces a rooftop ambient that is not the rating condition.

The gap is not small. The product's own record states that line-set length and vertical rise degrade capacity and energy efficiency ratio by 15-25% in many real-world installations. A selection made from the table and installed into that geometry is not a marginal misjudgement; it is a system chosen against a capacity it will not produce.

This paper describes a tool built on the premise that the installation is part of the machine. The line set, the ambient, the multi-circuit interaction and the defrost regime are selection inputs rather than commissioning discoveries.

1.1 Why direct expansion is harder than it looks

Direct expansion appears simpler than chilled water because there is no intermediate loop. That simplicity is deceptive: removing the water loop moves the refrigerant into the building, and refrigerant behaviour is sensitive to geometry in ways water is not. Pressure drop along the suction line reduces compressor suction pressure and therefore capacity; vertical rise imposes a static head that must be overcome; and oil return depends on velocity that depends on both.

Multi-circuit equipment adds a second interaction. Two circuits sharing a coil face do not operate independently, because the air leaving the first circuit's portion of the coil is the air entering the second's. Summing two independently rated circuits overstates the assembly.

> A chilled-water system hides its installation sensitivity inside a loop that a pump can be sized for. A direct-expansion system exposes it, which is why the selection has to carry the geometry.

1.2 Contributions

1. Capacity matching at the project's own entering and ambient conditions, with total and sensible duty treated as separate requirements rather than one.
2. A line-set correction driven by equivalent length and vertical rise, applied within the selection rather than after it.

3. A multi-circuit balance that solves circuits together through the shared air-side state instead of summing independent ratings.
4. Defrost-adjusted heating capacity reported across the winter ambient envelope, and an eight-dimension capability reference framework.

2 Background and Related Work

Two rating standards divide the direct-expansion market at a capacity boundary, and they measure efficiency differently on either side of it. A third regime — refrigerant regulation — increasingly constrains what may be selected at all.

2.1 Two standards, two metrics, one boundary

AHRI Standard 210/240 establishes definitions, classifications, test and rating requirements for factory-made unitary air conditioners and air-source heat pumps with capacities below 65,000 Btu/h. Its headline seasonal metric is the seasonal energy efficiency ratio, SEER2 — total heat removed across the annual cooling season divided by the electrical energy consumed.

AHRI Standard 340/360 covers commercial and industrial unitary equipment from 65,000 to 760,000 Btu/h — roughly 19 to 223 kW — for electrically operated vapour-compression systems. Its part-load metric is the integrated energy efficiency ratio, IEER, whose test method was simplified by removing the iterative outdoor-condition adjustments previously needed to reach each load point.

> The consequence for selection is easy to miss: two units either side of 65,000 Btu/h carry efficiency figures computed on different bases. Comparing a SEER2 against an IEER is not a comparison at all.

2.2 Refrigerant as a constraint on the circuit

Regulation (EU) 2024/573 on fluorinated greenhouse gases, in force from 11 March 2024 and repealing the earlier regulation, tightens the phase-down of hydrofluorocarbon production and consumption and sets phase-out dates where alternatives are feasible. For direct expansion this bites harder than for chilled water, because the refrigerant is distributed through the building rather than confined to a plant room.

Charge quantity, leak-check obligations and end-of-life recovery therefore become selection considerations. A system whose charge scales with line-set length carries a compliance and cost trajectory that a chilled-water alternative does not, and this is one of the terms a distributed-versus-central comparison must include.

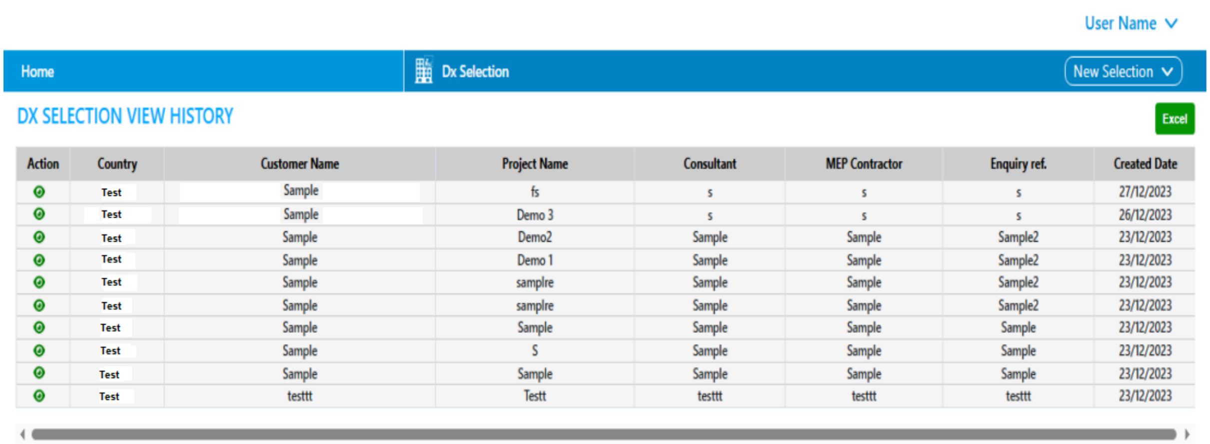
2.3 Failure modes of catalogue-driven DX selection

- Line set ignored. Capacity is taken at the rated condition with no correction for equivalent length or vertical rise, overstating delivered capacity by the 15-25% the product's record describes.

- Ambient assumed. The condenser is rated at a standard ambient rather than the rooftop condition it will face, which in hot climates is the larger of the two errors.
- Circuits summed. Multi-circuit equipment is rated as the arithmetic sum of independently rated circuits, ignoring the shared air-side state.
- Single heating figure. Heat-pump capacity is quoted at one ambient with no defrost debit, so the coldest hours — when the debit is largest — are described least well.
- Metrics compared across the boundary. A SEER2 figure is compared against an IEER figure as though they were the same quantity.

3 System Overview

The module is a browser-based selector organised as a project workflow: secure sign-in, a dashboard of selection projects, a guided new-selection path, and an exportable report.



Action	Country	Customer Name	Project Name	Consultant	MEP Contractor	Enquiry ref.	Created Date
	Test	Sample	fs	s	s	s	27/12/2023
	Test	Sample	Demo 3	s	s	s	26/12/2023
	Test	Sample	Demo2	Sample	Sample	Sample2	23/12/2023
	Test	Sample	Demo 1	Sample	Sample	Sample2	23/12/2023
	Test	Sample	samplre	Sample	Sample	Sample2	23/12/2023
	Test	Sample	samplre	Sample	Sample	Sample2	23/12/2023
	Test	Sample	Sample	Sample	Sample	Sample	23/12/2023
	Test	Sample	S	Sample	Sample	Sample	23/12/2023
	Test	Sample	Sample	Sample	Sample	Sample	23/12/2023
	Test	testtt	Testt	testtt	testtt	testtt	23/12/2023

Figure 1. The project dashboard. Direct-expansion selections are held as projects rather than as one-off calculations, so a selection can be reopened with the geometry and conditions it was made against.

3.1 The selection path

A new selection takes the required total and sensible capacity, the indoor entering condition, the design airflow, and the outdoor ambient, and returns conforming models with project pricing. Treating total and sensible capacity as two separate requirements rather than one is the first place this differs from a table lookup: a unit that meets total duty at the wrong sensible split will not hold the space condition.

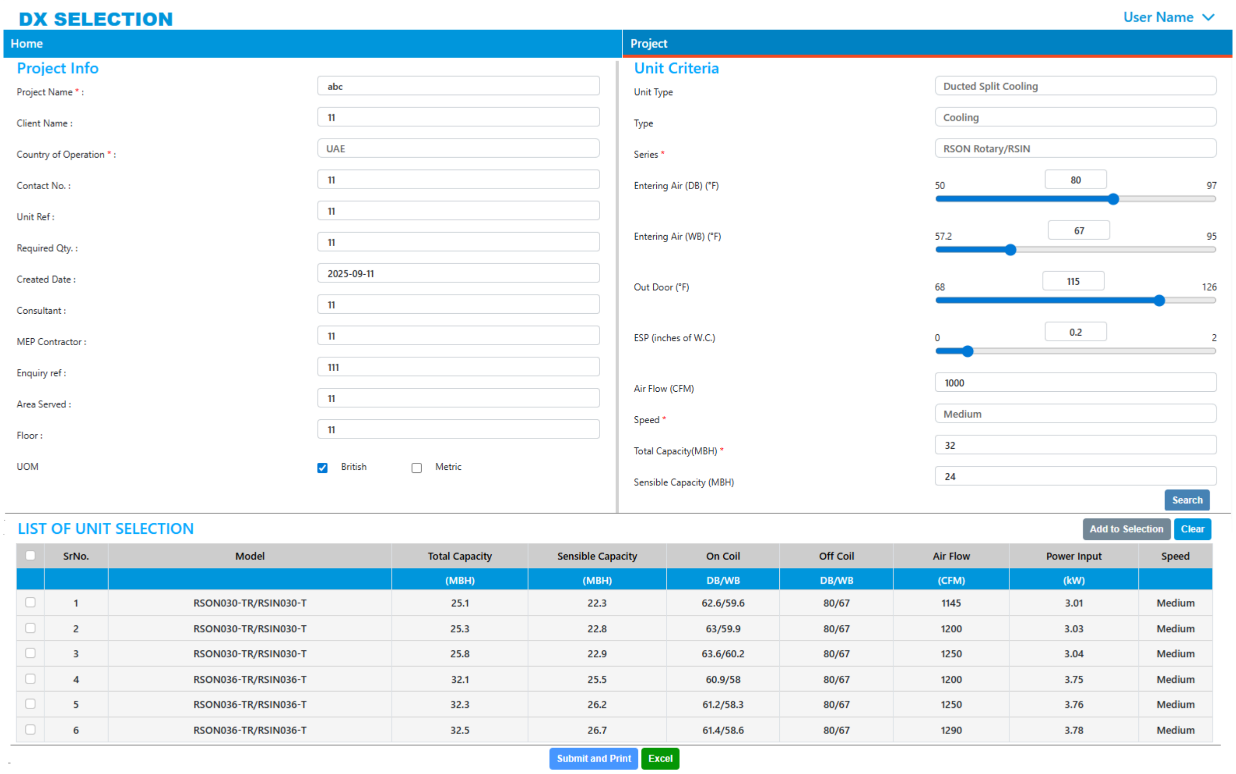
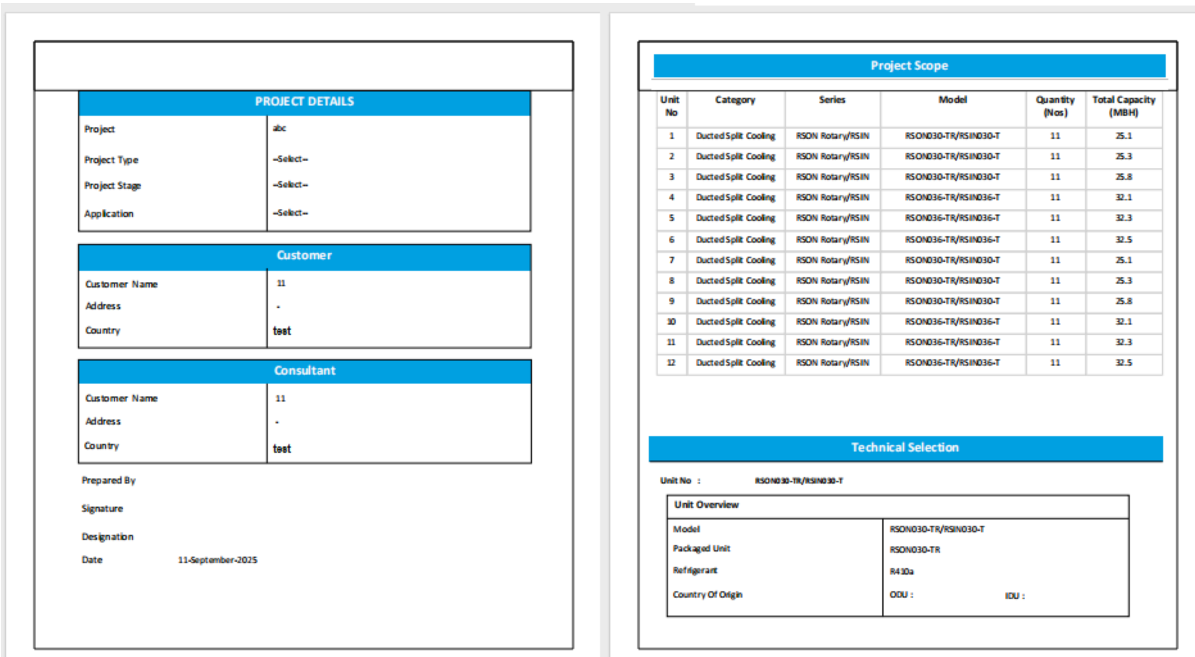


Figure 2. A new selection. Required total and sensible capacity are entered separately at the project's entering and ambient conditions. Because the implied sensible heat ratio is a selection constraint rather than an output, a unit that meets kilowatts but not the split is not returned as conforming.

The selection is embedded in a customer-relationship workflow that captures project stage, win probability and expected close — so a technical selection and its commercial context are one record rather than two.

3.2 Output

The report carries the selected model, the conditions it was selected at, and the corrected capacities rather than the catalogue values — which is the property that makes it checkable. A reviewer who recomputes the line-set penalty from the stated geometry should reproduce the reported capacity.



PROJECT DETAILS	
Project	abc
Project Type	--Select--
Project Stage	--Select--
Application	--Select--

Customer	
Customer Name	11
Address	-
Country	test

Consultant	
Customer Name	11
Address	-
Country	test

Prepared By

Signature

Designation

Date 11-September-2025

Project Scope

Unit No	Category	Series	Model	Quantity (Nos)	Total Capacity (MBH)
1	Ducted Split Cooling	RSON Rotary/RSIN	RSON030-TR/RSIN030-T	11	25.1
2	Ducted Split Cooling	RSON Rotary/RSIN	RSON030-TR/RSIN030-T	11	25.3
3	Ducted Split Cooling	RSON Rotary/RSIN	RSON030-TR/RSIN030-T	11	25.8
4	Ducted Split Cooling	RSON Rotary/RSIN	RSON036-TR/RSIN036-T	11	32.1
5	Ducted Split Cooling	RSON Rotary/RSIN	RSON036-TR/RSIN036-T	11	32.3
6	Ducted Split Cooling	RSON Rotary/RSIN	RSON036-TR/RSIN036-T	11	32.5
7	Ducted Split Cooling	RSON Rotary/RSIN	RSON030-TR/RSIN030-T	11	25.1
8	Ducted Split Cooling	RSON Rotary/RSIN	RSON030-TR/RSIN030-T	11	25.3
9	Ducted Split Cooling	RSON Rotary/RSIN	RSON030-TR/RSIN030-T	11	25.8
10	Ducted Split Cooling	RSON Rotary/RSIN	RSON036-TR/RSIN036-T	11	32.1
11	Ducted Split Cooling	RSON Rotary/RSIN	RSON036-TR/RSIN036-T	11	32.3
12	Ducted Split Cooling	RSON Rotary/RSIN	RSON036-TR/RSIN036-T	11	32.5

Technical Selection

Unit No : RSON030-TR/RSIN030-T

Unit Overview	
Model	RSON030-TR/RSIN030-T
Packaged Unit	RSON030-TR
Refrigerant	R410a
Country Of Origin	ODU : IDU :

Figure 3. The selection report. Reporting corrected rather than catalogue capacity is what allows a commissioning engineer to compare measured performance against a number that was actually predicted for this installation.

4 Computational Methods

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

4.1 Capacity matching at the project's conditions

A candidate must satisfy two duties simultaneously, evaluated at the project's indoor entering state and outdoor ambient rather than at the rating point.

$$Q(total)\ evaluated\ at\ entering,\ ambient\ and\ airflow >= Q(total\ required),\ AND\ Q(sensible)\ at\ the\ same\ conditions >= Q(sensible\ required) \quad \text{(match)}$$

the implied sensible heat ratio, Q(sensible required) / Q(total required), is a constraint rather than a result. A unit meeting only the first inequality will hold temperature and miss humidity.

Both capacities fall as outdoor ambient rises, but they do not fall together. Sensible capacity is comparatively robust; total capacity falls faster because the reduced pressure difference across the expansion device reduces mass flow. The sensible ratio therefore drifts upward with ambient, which is favourable in a dry climate and unhelpful in a humid one.

4.2 The line-set penalty

Refrigerant lines impose two distinct penalties. Frictional pressure drop along the equivalent length reduces compressor suction pressure, which reduces mass flow and therefore capacity. Vertical separation imposes a static head that must be overcome, and its sign depends on whether the evaporator is above or below the condenser.

$$Q(installed) = Q(rated) \times [\ 1 - k(L) \times L(equivalent) - k(H) \times H\ ] \qquad \text{(lineset)}$$

where L(equivalent) is the equivalent line length including fittings, H the vertical rise of the evaporator above the condenser, and k(L), k(H) manufacturer-published derating coefficients. Where the evaporator sits below the condenser, H is negative and the term is a small gain rather than a loss.

The published derating coefficients are per-model rather than universal, because they depend on line sizing, refrigerant and compressor characteristics. A tool that applies a single generic correction is producing a plausible-looking number with no manufacturer behind it, which is worse than applying none — it conceals the uncertainty instead of exposing it.

> The 15-25% figure in the product's record is the size of this correction in many real installations. Applying it after the selection means the selection was made against a capacity the system cannot reach.

4.3 Multi-circuit balance

Circuits sharing a coil face interact through the air-side state. The air entering the second circuit's portion of the coil has already been conditioned by the first, so the second circuit operates at a lower entering enthalpy and delivers less than its independent rating.

$$Q(total) = \text{SUM over circuits } c \text{ of } Q(c) \text{ evaluated at that circuit's entering enthalpy, where } h(in, c+1) = h(in, c) - Q(c) / m(air) \qquad \text{(circuits)}$$

the circuits are solved in sequence because each changes the state the next sees. The sum of independently rated circuits is an upper bound that the assembly does not reach.

The balance also matters for staging. When one circuit is off, the whole air-side flow passes over a coil with half its active surface, so the running circuit operates at a different point than it does when both are on. A selection that models only the fully loaded case says nothing about the part-load behaviour that dominates operating hours.

4.4 Defrost across the winter envelope

A heat pump's outdoor coil accumulates frost when its surface falls below both freezing and the ambient dew point. Defrost reverses the cycle or applies heat, consuming energy and suspending heating output for its duration.

$$Q(heating, \text{effective at ambient}) = Q(heating \text{ at ambient}) \times [\ 1 - \text{defrost duration} / \text{cycle period}\ ] - P(defrost) \qquad \text{(defrost)}$$

where the defrost duration and cycle period both vary with ambient temperature and humidity, and P(defrost) is the power consumed by the defrost mechanism. Effective capacity is therefore a curve across the winter envelope rather than a point.

The awkward property is that defrost frequency peaks in the humid-cold band — a few degrees either side of freezing — rather than at the coldest condition. A heat pump quoted at a low design ambient may be described more accurately there than at the milder, wetter condition where it will actually spend most of the heating season.

5 A Modelled Efficiency Case

This module appears in no published deployment case study. No field result is reported and none is claimed. What follows is the product's own published record plus a modelled scenario with its assumptions printed.

5.1 The one quantitative claim in the product's record

The published record for this module carries a single quantitative statement, and it is the one this paper is built around: line-set length and vertical rise degrade capacity and energy efficiency ratio by 15-25% in many real-world installations.

It is a claim about physics rather than about software, and it is the justification for the architecture. If the figure were 2-3%, treating the line set as a post-selection correction would be defensible. At 15-25% it is not, because a selection made against uncorrected capacity is selecting a different machine than the one that will be installed.

The rest of the published record is qualitative: precise performance calculations, refrigerant cycle validation and energy efficiency assessment for AHRI-certified companies. No deployment outcome, adoption figure or time saving is published for this module.

5.2 Modelled engineer-hour recovery

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

Parameter	Default
Manual selection time	60 minutes
Selection time in MileSoft	10 minutes
Selections per month	30
Engineer-hours released per year	300

The 60-minute baseline sits between the terminal-unit and chiller models, which is consistent with the equipment's complexity. As with the other modules in this series, it compares a manual method that most likely omits the line-set and multi-circuit corrections against an automated one that includes them — so the modelled saving understates the difference in work done, not only in time taken.

6 Discussion

6.1 Where the machine ends

The framing that produces good direct-expansion selections is that the machine does not end at the equipment schedule. A chilled-water system can be selected and the distribution designed separately, because the loop decouples them. A direct-expansion system cannot: the refrigerant circuit is simultaneously the machine and the distribution.

This has an organisational consequence. Where equipment selection and services routing are done by different people at different times, the line set is fixed after the unit is chosen — which is precisely the wrong order. A tool that requires equivalent length and rise as inputs forces the conversation earlier, which is arguably its most useful effect and the hardest to measure.

6.2 The 65,000 Btu/h discontinuity

The boundary between AHRI 210/240 and AHRI 340/360 is a rating discontinuity that appears nowhere in the physics. Below it, seasonal efficiency is expressed as SEER2; above it, part-load efficiency as IEER. The two are computed from different test procedures and are not interchangeable.

Selections near the boundary therefore need care. Comparing a 60,000 Btu/h unit's SEER2 against a 70,000 Btu/h unit's IEER produces a ranking with no meaning, and the temptation to do so is strong precisely where the capacity requirement sits close to the line. A selection tool should report the metric with its basis named rather than presenting a bare number.

6.3 A capability reference framework for direct-expansion 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 Line set as input	Is equivalent length and vertical rise required before a capacity is reported, or applied afterwards?
D2 Per-model derating	Are line-set coefficients taken from the manufacturer's data, or is one generic correction applied to every model?
D3 Project ambient	Is the condenser rated at the project's ambient or at a standard rating condition?
D4 Two duties	Are total and sensible capacity both constraints, or is sensible reported as an output?
D5 Circuit interaction	For multi-circuit equipment, are circuits solved through the shared air state or summed?
D6 Part-load staging	Is the single-circuit-running case modelled, or only the fully loaded one?
D7 Defrost curve	Is heating capacity reported across the winter envelope with defrost debits, or at one ambient?
D8 Metric basis named	Does the report state whether an efficiency figure is SEER2 or IEER, and its capacity band?

D1 is the fastest test and the most revealing. Ask for a capacity before supplying a line length. A tool that answers has not modelled the installation.

6.4 Generalisability

The line-set argument generalises to all split and variable-refrigerant-flow equipment and does not apply to packaged units where the circuit is factory-contained — for those, the ambient and multi-circuit terms remain and the line-set term vanishes. The 15-25% figure is a range across installations reported by the vendor, not a coefficient, and should be re-derived per model from manufacturer data rather than applied as a constant.

7 Threats to Validity and Limitations

1. No field evidence exists for this module. It appears in no published case study, so no claim in this paper is supported by a deployment result.
2. The 15-25% figure is a vendor-published range without a sample, a distribution, or a definition of the installations it describes. It is the paper's central premise and it rests on that single statement.
3. Derating is linear in the model presented. Equation (lineset) applies first-order coefficients in length and rise. Real behaviour is not exactly linear, particularly at long lengths where oil return becomes a limiting

consideration rather than a capacity one.

4. Circuit interaction is modelled sequentially. Equation (circuits) solves circuits in order through the air state. Real coil-face interaction includes lateral effects that a sequential treatment approximates.
5. Defrost parameters are difficult to obtain. Defrost duration and cycle period vary with ambient and humidity and are rarely published across the full envelope, so the curve is coarser than the equation implies.
6. Modelled ROI is not measurement. The 60-minute and 10-minute selection times are vendor estimates.
7. No cost data. Equipment, installation and refrigerant costs are not reported, so no return-on-investment conclusion is drawn.

> As with the ERV paper, a reader comparing this against the modules with published field results should weight it accordingly. Its methods are stated to the same standard; its evidence base is a single published range.

8 Future Work

- Measured line-set derating. Instrumenting installations across a range of equivalent lengths and rises would replace a vendor range with a distribution, and would show how much of the 15-25% is length and how much is rise.
- Non-linear derating at long runs. Extending Equation (lineset) beyond first order, and adding an oil-return feasibility limit, would make long-run selections safer rather than merely more conservative.
- Lateral coil-face interaction. Replacing the sequential circuit solution with a two-dimensional treatment of the coil face would test how much the sequential approximation costs.
- Published defrost envelopes. Working with manufacturers to publish defrost duration and period across ambient and humidity would turn Equation (defrost) from a structure into a usable curve.
- Distributed versus central lifecycle comparison. Carrying refrigerant charge, leak obligations and phase-down exposure into the Lifecycle Cost Analysis module would let distributed direct expansion be compared against central plant on the terms that now decide such projects.

9 Conclusion

A direct-expansion system is rated as a matched pair and installed as a refrigerant circuit through a building, and the difference between those two things is reported in this product's own record as 15-25% of capacity and efficiency in many real installations. A selection made from a catalogue table is therefore not a good approximation of the installed machine; it is a description of a different one.

This paper has described a tool that treats the installation as part of the machine: line-set equivalent length and vertical rise as selection inputs rather than post-selection corrections, condenser performance at the project's ambient, multi-circuit equipment solved through the shared air-side state rather than summed, and heat-pump heating reported across the winter envelope with defrost debits applied.

No deployment evidence is published for this module, and none is claimed here. The capability reference framework of Section 6.3 is offered as the durable contribution, and its first question takes one attempt to answer: ask the tool for a capacity before telling it the line length, and see whether it answers.

Appendix A Nomenclature

Table 3. Symbols and abbreviations used in this paper.

Symbol / term	Meaning
Q(total), Q(sensible)	Total and sensible cooling capacity at the stated conditions
Q(total required)	Total cooling duty the space demands
T(entering air)	Dry-bulb temperature of air entering the indoor coil
T(ambient)	Outdoor air temperature at the condenser
V(flow)	Design airflow across the indoor coil
Q(rated)	Capacity at the standard rating condition and line length
Q(installed)	Capacity after line-set correction at the installed geometry
L(equivalent)	Equivalent refrigerant line length including fittings
H	Vertical rise of the evaporator above the condenser; negative if below
k(L), k(H)	Manufacturer-published derating coefficients for length and rise
h(in, c)	Air enthalpy entering circuit c of a multi-circuit coil
m(air)	Air-side mass flow across the coil
Q(heating, effective)	Heat-pump heating capacity after defrost debits
t(d), t(c)	Defrost duration and defrost cycle period
P(defrost)	Power consumed by the defrost mechanism
SEER2	Seasonal energy efficiency ratio under AHRI 210/240, below 65,000 Btu/h
IEER	Integrated energy efficiency ratio under AHRI 340/360, 65,000 to 760,000 Btu/h
DX	Direct expansion
VRF	Variable refrigerant flow

Appendix B Worked Numerical Examples

Appendix B.1 What the line set costs

A split system is rated at 30 MBH total and 25 MBH sensible — an implied sensible heat ratio of 0.83 — at 1,000 cfm with a 7.5 m equivalent line length. The installation runs 45 m equivalent with the evaporator 18 m above the condenser. Published derating coefficients for the model are k(L) = 0.0022 per metre beyond the rating length and k(H) = 0.0035 per metre of rise.

Excess length is 45 — 7.5 = 37.5 m. Applying Equation (lineset): Q(installed) = 30 x [1 — 0.0022 x 37.5 — 0.0035 x 18] = 30 x [1 — 0.0825 — 0.0630] = 30 x 0.8545 = 25.6 MBH.

The unit delivers 25.6 MBH against a catalogue 30 MBH — a 14.5% shortfall, inside the range the product's record describes. A space requiring 28 MBH would have been satisfied by this selection on paper and under-served by 8% in practice. Note also that the rise term, at 6.3%, contributes almost as much as 37.5 metres of length at 8.3% — vertical separation is the more punishing variable per metre.

Appendix B.2 Why two circuits are not twice one circuit

A two-circuit coil handles 1.9 kg/s of air entering at 62.0 kJ/kg. Each circuit is independently rated at 24 kW at that entering enthalpy.

Summing gives 48 kW. Applying Equation (circuits): circuit 1 delivers 24 kW at h(in,1) = 62.0 kJ/kg. The air entering circuit 2 is then h(in,2) = 62.0 — 24 / 1.9 = 62.0 — 12.63 = 49.4 kJ/kg. At that lower entering enthalpy circuit 2 delivers less — suppose the model returns 20.4 kW.

Assembly total is 24 + 20.4 = 44.4 kW against a summed 48 kW, an overstatement of 8.1%. The error compounds with circuit count: a four-circuit coil summed independently can overstate by well over 15%, and the overstatement is largest exactly where the equipment is largest.

> Combine this with the line-set example and the two errors are multiplicative, not additive. A four-circuit unit on a long riser can be specified at close to 25% above what it will deliver.

Appendix B.3 The published engineer-hour model

MileSoft's published model assumes a manual direct-expansion selection takes about 60 minutes against about 10 minutes in the tool, at 30 selections per month.

Time saved per selection is (60 — 10) / 60 = 0.8333 h. Annual selections are 30 x 12 = 360. Engineer-hours released are 0.8333 x 360 = 300 h per year.

The comparison is not like for like, and the direction matters. Sixty minutes is a reasonable estimate for a catalogue selection with an ambient correction. It is not enough time to apply per-model line-set coefficients, solve a multi-circuit balance and build a defrost-adjusted heating curve. The model therefore prices a simpler manual task against a more complete automated one — which understates the saving while overstating how comparable the two outputs are.

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
Capacity and EER degradation from line-set length and vertical rise	15-25% in many real installations	**Product specification** /products/dx — Stated in the DX blog post; the reason catalogue tables mis-size real installations.
Capacity band rated under AHRI 340/360 with the integrated energy efficiency ratio	65,000 to 760,000 Btu/h (19-223 kW)	**Defined by AHRI Standard 340/360 (I-P)** Below this band equipment is rated under AHRI 210/240 on SEER2 instead, so two capacities either side of the boundary are not directly comparable.
Engineer-hours released per year, DX selection	300 h/yr (modelled)	**Modelled estimate** A manual DX selection takes ~60 min; ~10 min in MileSoft; 30 selections per month, 360 per year; Model and defaults published in src/data/roiModels.ts

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