Supply-Air Cooling Potential of Direct and Indirect-Direct Evaporative Cooling for South-South Nigerian Buildings

Emmanuel Udama Odeh[1]
Department of Mechanical and Aerospace Engineering
University of Uyo, Uyo, Akwa Ibom State, Nigeria
emmanuelodeh@uniuyo.edu.ng

Uwah Etebom Francis[2]
Department of Mechanical and Aerospace Engineering
University of Uyo, Uyo, Akwa Ibom State, Nigeria
francis.nerster@gmail.com

Damilare Titus Adebisi[3]
Department of Mechanical and Aerospace Engineering
University of Uyo, Uyo, Akwa Ibom State, Nigeria
dtadebisi@gmail.com

Abstract

Low-energy cooling systems for South-South Nigerian buildings must first demonstrate whether they can deliver stable supply air under humid outdoor conditions. This assessment examines the supply-air cooling potential of DEC and IDEC using a 16-hour operating record. The mean supply temperature from IDEC was 19.23 °C, while DEC averaged 24.75 °C. The IDEC outlet-temperature range was 0.17 °C, compared with 10.62 °C for DEC, and mean cooling efficiency improved from 64.05% to 91.30%. These values show that IDEC provides a stronger supply-air basis for later room-scale comfort testing. Full comfort compliance still requires measurements of operative temperature, indoor relative humidity, air speed, mean radiant temperature, clothing insulation and metabolic rate.

Keywords: supply-air cooling potential; humid-climate cooling; IDEC; ASHRAE 55 screening; Nigeria

1. Introduction

Thermal comfort depends on air temperature, humidity, air speed, mean radiant temperature, clothing and metabolic rate [1]. In practice, however, early-stage cooling design often begins with supply-air temperature because it determines how much sensible cooling and ventilation preconditioning can be offered to the zone [2]. In hot-humid climates, the supply-air problem is difficult because outdoor humidity limits evaporative potential and raises the risk of moisture discomfort [3].

Nigeria includes hot-humid and warm-humid regions where cooling demand is high and electricity supply is often constrained [4]. Conventional vapour-compression systems can provide good comfort control, but they add compressor power and refrigerant-related environmental burdens [5]. Evaporative cooling offers a lower-energy route, especially where ventilation and preconditioning are acceptable design goals [6]. Direct evaporative cooling is simple, while indirect-direct cooling can improve performance by lowering the air temperature before direct humidification [7], [8], [9], [10].

This assessment examines supply-air cooling potential rather than complete room comfort. The distinction is important because an outlet temperature alone cannot prove comfort compliance. It can, however, show whether a configuration is worth taking forward to room-scale testing.

2. Methodology

2.1 Research process flowchart

Figure 1 presents a standard research process flowchart for the supply-air cooling-potential assessment. The flowchart is positioned at the beginning of the methodology section so that the screening logic and the later discussion of comfort-related variables can be followed in a single sequence.

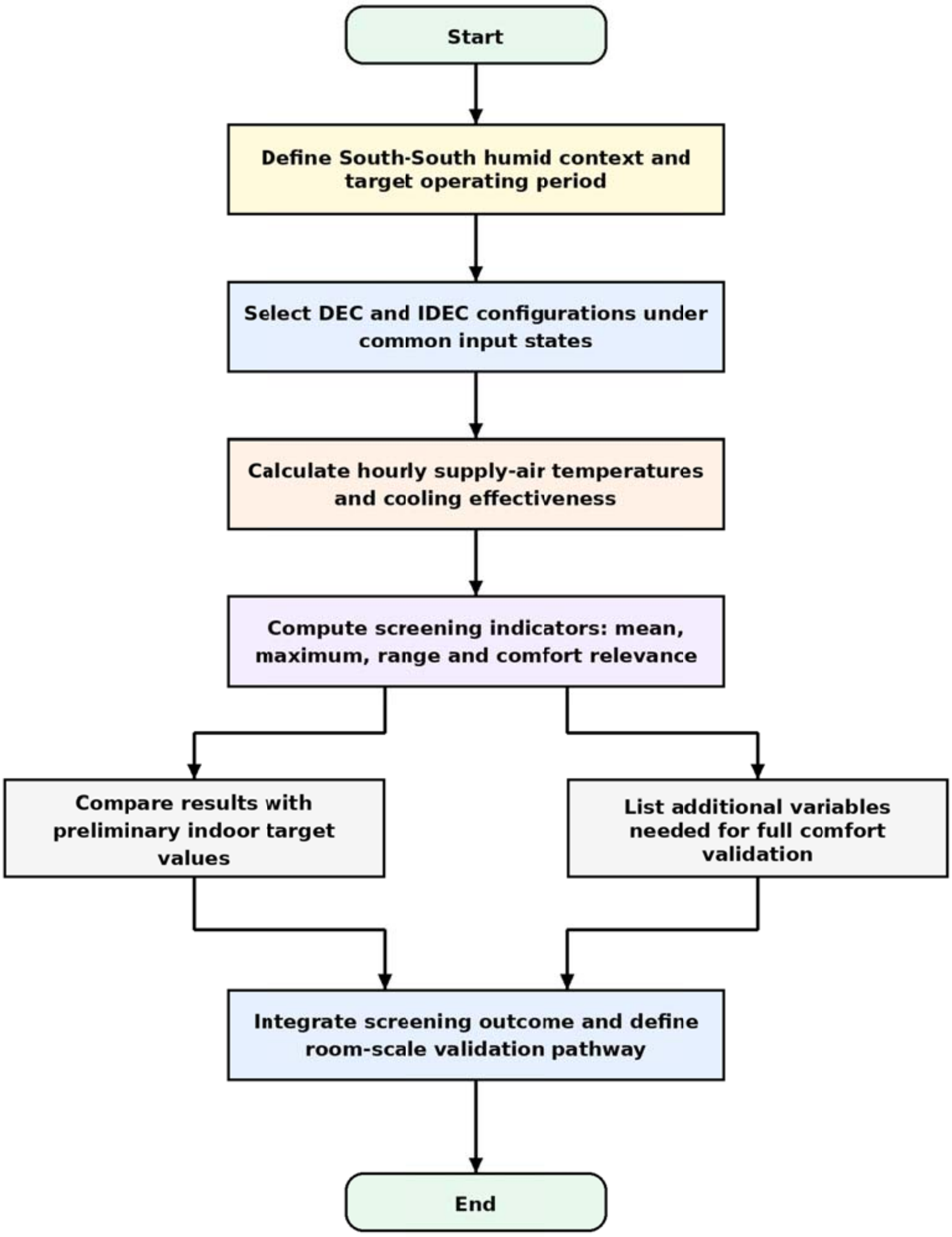

Figure 1. Standard research process flowchart for the supply-air cooling-potential assessment.

The flowchart runs downward through the screening procedure and then splits into two clearly directed branches. After the humid context, compared configurations and hourly supply-air calculations are defined, the screening indicators are computed. One branch compares the results with preliminary indoor targets, while the other branch identifies the additional variables required for a full comfort assessment. Both branches feed into the final validation pathway.

Supply-air temperature was used as the screening variable because full comfort compliance also depends on operative temperature, relative humidity, air speed, mean radiant temperature, clothing insulation and metabolic rate. The method therefore reports mean supply temperature, maximum supply temperature, range and mean cooling efficiency, while listing the room variables that must be measured during ASHRAE-type validation.

Table 1. Indicative indoor target conditions used for preliminary screening.

Space	Summer DB target	Summer RH target	Winter DB target	Winter RH target
Workshop	24 °C	40-50%	22 °C	40-50%
Office	24 °C	40-50%	22 °C	40-50%
Store	24 °C	40-50%	22 °C	40-50%
Lobby	24 °C	40-50%	22 °C	40-50%
Staircase	24 °C	40-50%	22 °C	40-50%
Equipment room	24-26 °C	40-50%	18-22 °C	40-50%

The supply-air assessment used the 16-hour operating record for DEC and IDEC. Four indicators were calculated: mean supply temperature, maximum supply temperature, temperature range and mean cooling efficiency. These indicators show whether a system can provide a stable cooled stream before considering room mixing, internal gains and occupant exposure.

$$\bar{T}_{sup} = \frac{1}{n}\sum_{i=1}^{n} T_{sup,i} \quad (1)$$

$$R_T = T_{sup,max} - T_{sup,min} \quad (2)$$

$$\Delta T_{sup} = T_{db,amb} - T_{sup} \quad (3)$$

Table 2. Variables required for complete thermal comfort assessment.

Variable	Included in this study?	Reason for inclusion in future work
Supply-air dry-bulb temperature	Yes	Primary screening indicator
Occupied-zone operative temperature	No	Needed for ASHRAE 55 compliance
Relative humidity in occupied zone	No	Controls moisture comfort and mould risk
Air speed	No	Affects allowable comfort temperature
Mean radiant temperature	No	Important in lightweight buildings
Clothing insulation and metabolic rate	No	Needed for PMV/PPD or adaptive comfort
PMV/PPD or adaptive comfort result	No	Required for formal comfort claim

The comfort boundary was defined using the variables required for a later ASHRAE 55-type room assessment: operative temperature, indoor relative humidity, air speed, mean radiant temperature, clothing insulation and metabolic rate. The present analysis reports the available supply-side quantities and identifies the room-scale measurements that must be added during prototype validation. In this way, the methodology separates equipment performance from occupied-zone comfort response.

The assessment used supply-air temperature as a screening variable because it is the first measurable output of the cooling unit and the most direct indicator of whether the system can contribute useful cooling before room mixing occurs. This is not the same as full comfort certification; it is a pre-comfort screening stage that determines whether the cooling unit is worth testing inside a room.

3. Results

DEC was able to meet a 24 °C supply target during some early hours but failed to hold that condition later in the day. Its maximum supply temperature of 30.35 °C is too high for direct use as comfort cooling air without additional conditioning or high ventilation air speed. IDEC supplied a much colder and steadier air stream. Its 19.15-19.32 °C outlet band would provide greater mixing margin for spaces with internal gains.

The supply-air result is therefore a preconditioning indicator. A 19.23 °C supply stream gives the room system a stronger starting point, but the final comfort outcome depends on humidity control, air distribution, radiant temperature and internal moisture gains. It does mean that the IDEC configuration has a stronger sensible cooling basis than DEC and should be prioritised for prototype room testing.

Table 3. Supply-air cooling potential indicators.

Indicator	DEC	IDEC
Mean supply temperature	24.75 °C	19.23 °C
Minimum supply temperature	19.73 °C	19.15 °C
Maximum supply temperature	30.35 °C	19.32 °C
Supply temperature range	10.62 °C	0.17 °C
Mean efficiency	64.05%	91.30%

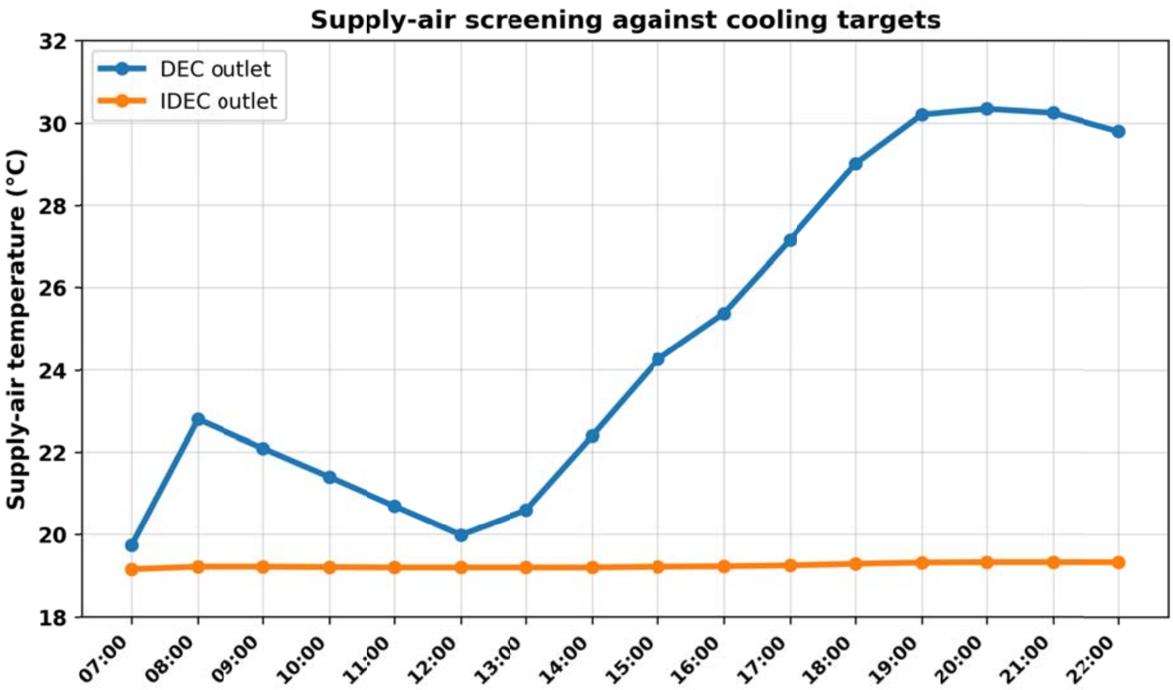

Figure 2. Supply-air temperature response over the 16-hour operating sequence.

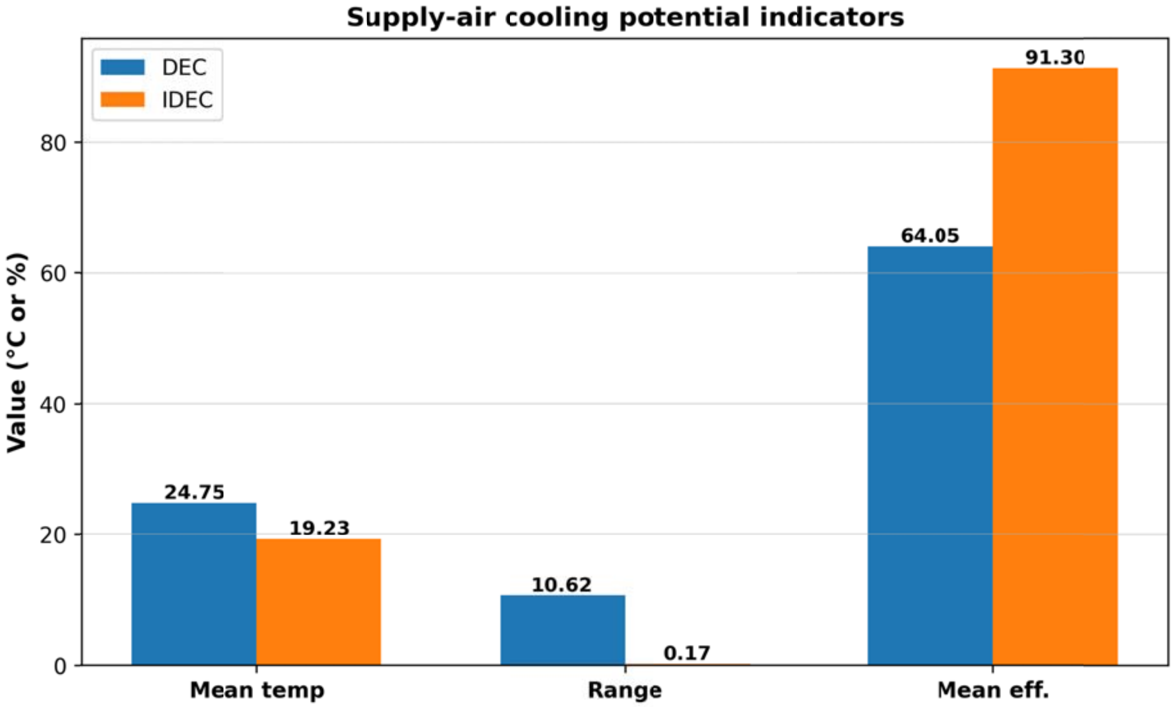

Figure 3. Summary indicators for supply-air cooling potential.

4. Discussion

A useful supply-air result is only the first part of the comfort chain. In South-South Nigerian buildings, the next design step should couple the supply-air temperature with indoor humidity, air distribution, envelope heat gain and occupant schedule. This room-scale step will show whether the cool supply stream lowers operative temperature without pushing relative humidity beyond an acceptable range.

Supply-air stability matters in South-South Nigeria because high humidity reduces the tolerance for warm indoor air. A cooling unit with a rising outlet temperature may perform acceptably at the start of the day and poorly when outdoor heat gain and occupancy load increase. The IDEC record avoids that weakness by keeping the supply temperature nearly constant. In a real building, the final comfort outcome will depend on airflow rate, distribution pattern, internal heat gains, envelope heat transfer and moisture removal strategy.

5. Conclusion

IDEC showed stronger supply-air cooling potential than DEC for hot-humid South-South Nigerian operation. Mean supply temperature decreased from 24.75 °C to 19.23 °C, and supply-temperature range fell from 10.62 °C to 0.17 °C. The result supports IDEC as a better preconditioning option, while leaving full thermal comfort confirmation to room-scale measurement.

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