

Challenges in Mongolia's building cooling systems sector: A survey of industry professionals

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Abstract. Driven by global warming and rapid urbanization, summer air temperatures in Mongolia are rising and cooling demand in commercial and public buildings is growing steadily. Research systematically examining the challenges faced across the design, installation, and operation stages of cooling systems remains limited, however, and no independent calculation platform adapted to Mongolia's climatic conditions has yet been established.

This study characterizes the current state of the sector, identifies the challenges faced by industry professionals, and assesses the need for an independent calculation platform to improve the quality of cooling system design and operation. Using purposive sampling, 40 heating, ventilation, and air-conditioning (HVAC) professionals were surveyed: 18 design engineers, 14 installation engineers, and 8 operation engineers and technicians. Data were collected in March 2026 via a conditional, branched questionnaire hosted on the coolcalc.mn online platform.

Results show that 88.9% of design engineers rely on an experience-based rule-of-thumb (W/m^2) sizing approach, while only 16.7% apply the ASHRAE load-calculation procedures, and 50.0% calculate neither capital expenditure (CAPEX) nor operating expenditure (OPEX). Among installation engineers, 92.9% reported that space for equipment placement is not allocated in the design, and 92.9% highlighted a shortage of qualified operations personnel. Only 25.0% of operation engineers reported that their systems are fully operational; 62.5% of this group identified insufficient operational knowledge as the sector's most critical issue. Across all respondents, 90.0% expressed interest in a brand-neutral calculation platform aligned with international standards.

The findings indicate a need for a locally adapted, standards-compliant calculation tool, alongside reforms in professional training and regulatory codes, to improve building energy efficiency and support Mongolia's sustainable urban development goals.

Keywords: cooling load calculation, energy efficiency, HVAC, operational knowledge, building codes

1 Introduction

Mongolia's long-term policy Vision 2050 [1] sets out goals for transitioning to an energy-efficient, low-carbon economy and reducing urban air pollution through "green" construction. Within this framework, the Law on Energy Conservation (2015) [2] and the sectoral construction codes currently in force — BNbD 41-01-11 Heating, Ventilation and Air Conditioning [3] and BNbD 25-01-20 Thermal Protection of Buildings [4] — fulfill the principal regulatory functions for building energy performance. Climate change and the urban heat island (UHI) effect, however, are observed with increasing intensity in Ulaanbaatar: Ganbat et al. [5] report an annual mean UHI intensity of 1.6 °C, with a daily maximum of 4.3 °C and with a strong seasonal dependence — being strongest in winter (3.3 °C) and weakest in summer (0.3 °C).

Globally, energy demand for space cooling is projected to triple by 2050, becoming a significant driver of world energy demand [6]. In Mongolia, although the summer season is short, it is marked by high intensity due to the country's extreme continental climate. Compounded by the Ulaanbaatar UHI and the rising demand for modern glass-façade buildings, solar radiation loads on building envelopes have increased, sustaining the rise in mechanical cooling demand in commercial and public buildings.

The capacity to properly design, calculate, install, and operate these systems in Mongolia, however, lags considerably behind international benchmarks — the ASHRAE Handbook — Fundamentals [7], ISO 52016-1:2017 [8], and ASHRAE Standard 90.1 [9]. At the design stage, oversizing — often driven by reliance on simplified rule-of-thumb (W/m^2) approaches not grounded in local climatic data — leads to energy waste [10] and, by extension, adverse environmental consequences. The absence of integrated analysis covering both capital expenditure (CAPEX) and operating expenditure (OPEX) further limits assessment of a system's true economic performance; installed systems are consequently sometimes left unused, wasting the initial investment — a pattern also reported by respondents in this study.

The objectives of the present study are therefore: (1) to identify the tools, methods, and challenges encountered by professionals at each stage of the cooling system lifecycle — design, installation, and operation; (2) to evaluate the need for an independent calculation platform suited to Mongolian conditions; and (3) to formulate recommendations for subsequent policy and technical solutions.

2 Research methodology

2.1 Research design and reference standards

A quantitative research design was adopted, using a conditional (branched) questionnaire as the data collection instrument. The questionnaire was developed on the basis of four reference standards: the cooling load calculation procedures in the ASHRAE Handbook — Fundamentals [7]; the energy performance requirements for heating and cooling in ISO 52016-1:2017 [8]; the building energy standard ASHRAE

Standard 90.1 [9]; and the national code BNbD 41-01-11 [3]. Accordingly, the items were targeted at respondents' professional competencies, the tools currently in use, and the challenges they encounter in practice.

2.2 Sampling and data collection

Purposive sampling was employed, and professionals in the heating, ventilation, and air conditioning (HVAC) sector were recruited through professional networks and direct invitation. Data collection was conducted in March 2026 via the coolcalc.mn online platform. At the time of data collection, coolcalc.mn served as a survey-hosting platform; its planned development into a full calculation tool is one of the outcomes recommended by this study. In total, 40 professionals participated and were classified into three groups: design engineers (n = 18; 45.0%), installation engineers (n = 14; 35.0%), and operation engineers and technicians (n = 8; 20.0%) (Fig. 1).

In terms of professional experience, 12.5% of respondents (n = 5) had 2–5 years, 37.5% (n = 15) had 5–10 years, and 50.0% (n = 20) had more than 10 years. Accordingly, 87.5% of the sample had more than five years of professional experience, supporting the interpretive weight of the findings for characterizing current sector conditions.

2.3 Questionnaire structure

The questionnaire was organized in three blocks. Block 1 collected general information: organization, years of experience, professional category, building type worked on, total floor area, and number of stories. Block 2 comprised technical items branched by professional group — 9 items for design engineers, 9 for installation engineers, and 10 for operation engineers and technicians. Block 3 contained common closing items on regulatory codes, passive cooling, and willingness to use brand-independent tools. Responses were processed quantitatively in Python 3.11 with the Matplotlib library; frequencies and percentage shares were computed and visualized.

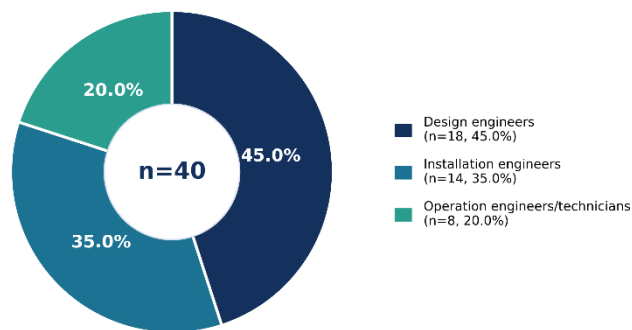


Figure 1. Distribution of participants by professional group (n = 40)

3 Results

3.1 Design stage

The capacity calculation methods used by design engineers ($n = 18$) are shown in Fig. 2. An overwhelming 88.9% of respondents rely on an experience-based rule-of-thumb (W/m^2) sizing approach, indicating that personal-experience-driven practice prevails over the application of physically based standard procedures. Manufacturer software (e.g., Carrier HAP, LG LATS, Daikin VRV Design) is used by 38.9%, while only 16.7% apply the ASHRAE load-calculation procedures. With respect to the use of design weather data, 55.6% of respondents reported incomplete or inadequate use — 38.9% partial and 16.7% international or unspecified data — indicating that the incorporation of detailed domestic design weather data into calculations is weak.

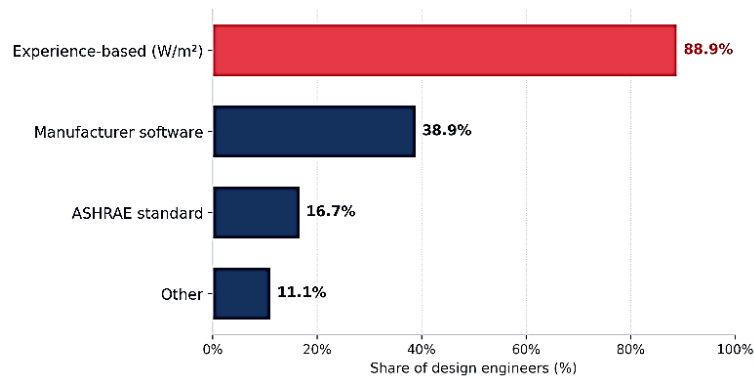


Figure 2. Capacity calculation methods reported by design engineers ($n = 18$; multi-select)

The main challenges encountered during the design process are presented in Fig. 3. Client demands for low-cost equipment were identified as the principal challenge by 66.7% of respondents, followed by a lack of collaboration with installation engineers (50.0%) and difficulties in estimating operating expenditure (OPEX, 27.8%). These factors bear directly on the quality of design outputs.

With respect to oversizing, 38.9% of design engineers (7/18) reported having oversized system capacity themselves (11.1% often; 27.8% sometimes). Among this subgroup ($n = 7$), the principal reasons were experience-based decision-making (71.4%) and an excessive safety factor (57.1%), whereas client requirements and insufficient actual-load data accounted for 14.3% each. This pattern indicates that, in Mongolian design practice, oversizing is driven by personal experience and a risk-averse mindset rather than by standardized calculation procedures.

Furthermore, 61.1% of design engineers do not perform a complete economic evaluation — 50.0% calculate neither CAPEX nor OPEX, and 11.1% calculate only one of the two — confirming that economic performance analysis is inadequately addressed at the design stage.

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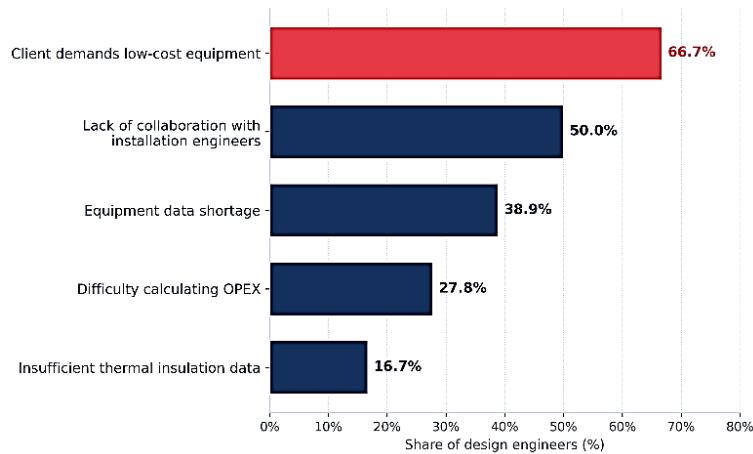


Figure 3. Challenges encountered during design development (n = 18; multi-select).

3.2 Installation stage

Among installation engineers (n=14; multi-select), 78.6% work with variable refrigerant flow (VRF) and split systems, 64.3% with air-cooled chillers, and 50.0% with water-cooled chillers, confirming that VRF technology predominates in the Mongolian market. The most commonly reported issues at the installation stage include discrepancies between design and actual on-site conditions (71.4%), routing conflicts between pipework and cable trays (71.4%), and conflicts with the building's structural elements (64.3%), all of which indicate insufficient coordination between the design and installation stages.

Installation engineers' assessments of common design errors are shown in Fig. 4. The most prevalent error, reported by 92.9% of respondents, is the failure to allocate space for equipment placement in the design. Other predominant issues are undersizing (64.3%) and the omission of auxiliary equipment (50.0%). These findings indicate that the design stage does not adequately capture the real-world spatial and engineering requirements of installation.

3.3 Operation stage

The majority of systems maintained by operation engineers (n = 8) are water-cooled chillers (75.0%), reflecting the inclusion of large commercial and public buildings in the sample. Other frequently maintained systems include air-cooled chillers (50.0%) and VRF and split systems (37.5% each).

The current operational status of these systems is among the study's most notable findings: as shown in Fig. 5, only 25.0% of systems operate at full capacity, 62.5% are partially operational, and 12.5% are switched off. In other words, 75.0% of systems are not running under optimal conditions, giving rise to reduced energy efficiency, degraded indoor air quality, and the underutilization of initial capital investment.

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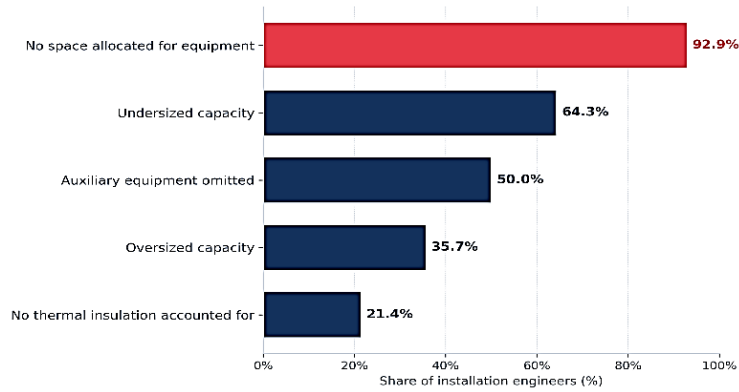


Figure 4. Common design errors identified by installation engineers (n = 14; multi-select).

3.4 Operation stage

The majority of systems maintained by operation engineers (n = 8) are water-cooled chillers (75.0%), reflecting the inclusion of large commercial and public buildings in the sample. Other frequently maintained systems include air-cooled chillers (50.0%) and VRF and split systems (37.5% each).

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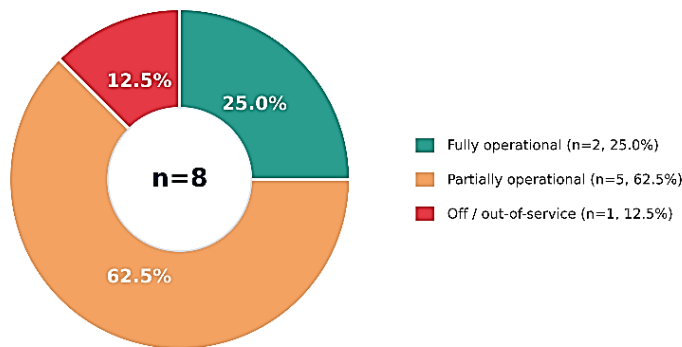


Figure 5. Current operational status of cooling systems (n = 8).

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With respect to operational challenges, 37.5% of respondents cited high electricity costs, while 25.0% each identified a shortage of qualified technicians and a lack of funding from management as pressing concerns. The most widespread causes of system failure were control-panel malfunctions (62.5%) and repairs delayed by the absence of technicians (50.0%). The monthly electricity cost of cooling systems exceeds MNT 5 million for 75.0% of respondents, indicating that cooling systems constitute a significant component of a building's operating expenditure. Considered together with the operational status noted above — only 25.0% fully operational — this high cost points to substantial scope for improving operational efficiency.

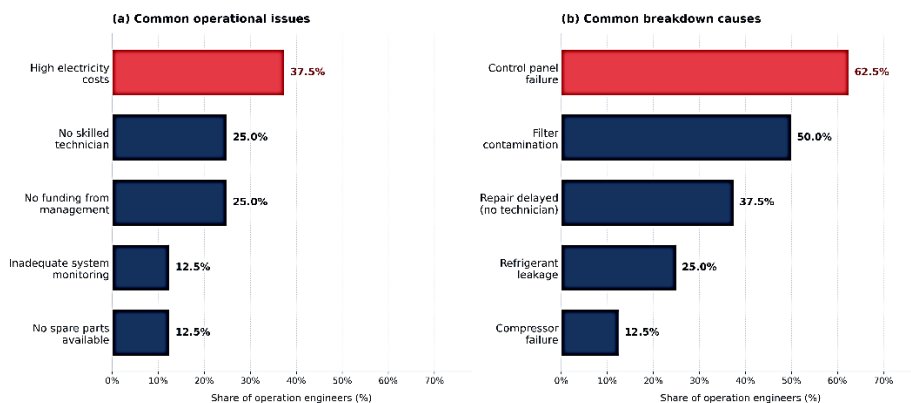


Figure 6. Common operational issues and causes of system failure reported by operation engineers (n = 8; multi-select).

3.5 Sector-wide cross-analysis

All 40 respondents were asked the single-choice question, "What is the most critical issue facing Mongolia's cooling sector?"; the results are shown in Fig. 7. Insufficient operational knowledge (32.5%) was identified as the sector's leading issue, followed by design quality (22.5%) and electricity costs (17.5%). Notably, the professional groups assigned priority differently: 62.5% of operation engineers regarded the shortage of operational knowledge in their own field as the most critical issue, whereas 42.9% of installation engineers identified design quality as the principal obstacle — indicating that the design–installation coordination problem persists. Among design engineers, operational knowledge and electricity costs were cited most frequently, each by 27.8% (5/18), suggesting that these engineers weight the two concerns equally.

To the question "Is a dedicated regulatory code for cooling load calculation tailored to Mongolian conditions needed?", 12 respondents answered. Of these, 91.7% (11/12) considered that a dedicated code adapted to Mongolia's climate and building characteristics is required — 50.0% answered "necessary" and 41.7% "strictly necessary" — while only 8.3% regarded the existing code as sufficient. This finding supports the need

to develop a national cooling standard grounded in Mongolia's extreme continental climate and specific solar-radiation conditions.

To the question "Is there scope to apply passive (free) cooling technology in the buildings you work on?", 66.7% of respondents (8/12) answered that it is partially feasible, while 33.3% (4/12) regarded it as not feasible at all (Fig. 8). These responses suggest that Mongolia's cool summer nights and cold winter conditions offer opportunities to reduce mechanical cooling loads and to deliver tangible energy savings.

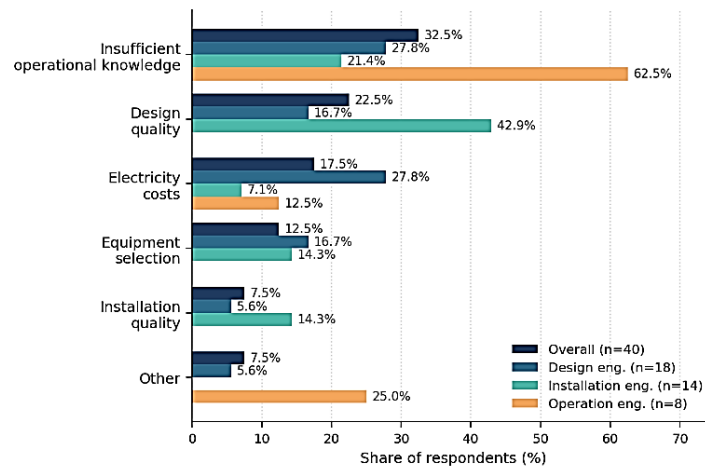
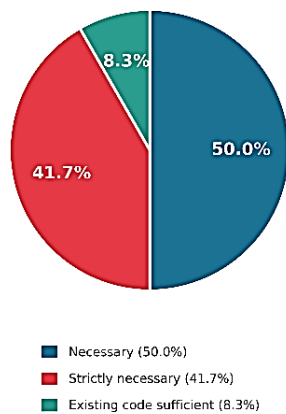


Figure 7. Most critical issue facing the sector — overall and by professional group (n = 40).

(a) Need for a tailored cooling standard



(b) Feasibility of passive (free) cooling

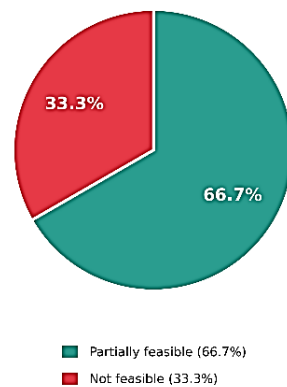


Figure 8. Need for a cooling standard tailored to Mongolian conditions and feasibility of passive (free) cooling (n = 12).

3.6 Need for an independent calculation platform

One of the study's key items — "Would you use an independent, brand-neutral calculation tool if one were available?" — produced the results shown in Fig. 9. Overall, 90.0% of respondents (36/40) answered positively: 57.5% "would definitely use" and 32.5% "might use" such a tool. By professional group, positive responses were reported by 100% of installation engineers (14/14), 88.9% of design engineers (16/18), and 75.0% of operation engineers (6/8). The unanimous endorsement by installation engineers is of particular note, as it underscores the potential of a new tool to improve design–installation coordination. These findings confirm a clear market need for a national calculation platform such as coolcalc.mn.

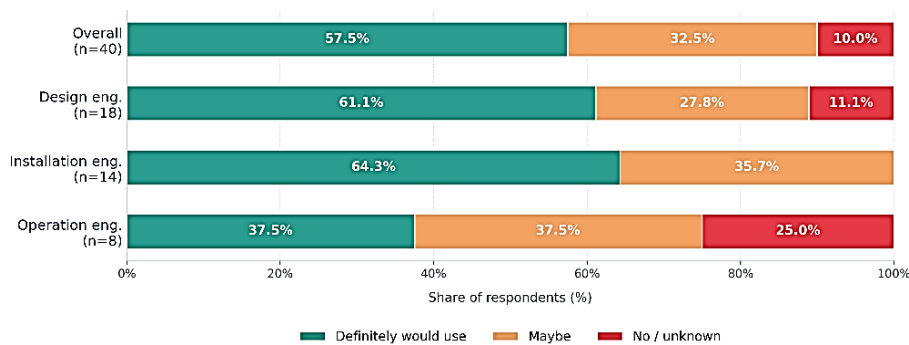


Figure 9. Willingness to use a brand-neutral calculation tool, by professional group.

4 Discussion

4.1 Design-stage methodology and its physical limitations

The finding that 88.9% of design engineers rely on an experience-based W/m^2 method while only 16.7% apply the ASHRAE procedure points to a methodological issue whose nature is often understated in Mongolian practice. The W/m^2 coefficient is an empirical shortcut intended for rapid, indicative estimation; it is not designed to substitute for a physical representation of cooling loads. By contrast, the Heat Balance (HB) and Radiant Time Series (RTS) methods defined in the ASHRAE Handbook — Fundamentals [7] and the hourly calculation procedure specified in ISO 52016-1:2017 [8] are explicitly formulated to capture the dynamic processes — transient conduction, solar gain variation, and internal gain scheduling — that determine actual peak cooling demand. The gap between these two classes of method is therefore not merely one of standards compliance; it is a gap between estimation and physical representation. As Burdick [10] observes in the context of residential load calculations — a principle equally applicable at the commercial scale — the accuracy of cooling and heating load calculations depends directly on whether such physical processes are modeled at all.

It is equally important, however, to note what these international procedures do and do not provide. Neither the ASHRAE Handbook [7] nor ISO 52016-1 [8] was developed specifically for Mongolia's extreme continental climate, its high-altitude urban heat-island regime [5], or the rapidly increasing penetration of glass-façade construction. The appropriate framing, then, is not that Mongolian practice should "follow" ASHRAE or ISO in a narrow sense, but that the physically rigorous foundations of these procedures should be adapted to Mongolian climatic inputs and building typologies. The current 88.9% reliance on W/m² methods leaves no scaffold on which such adaptation can be built.

The observed oversizing pattern is particularly informative in this respect. Of the 38.9% of design engineers who acknowledged having oversized system capacity themselves (11.1% often; 27.8% sometimes), 71.4% attributed the decision to experience-based judgment and 57.1% to an excessive safety factor, whereas client demands and insufficient load data accounted for only 14.3% each. The principal drivers are thus internal to engineering practice rather than external pressures. This is consistent with oversizing functioning as a form of risk insurance under methodological uncertainty: when engineers lack confidence in the calculation procedure or in the local climatic inputs available to them, they respond by adding capacity margins. Rational at the individual level, this response collectively entrenches the energy inefficiency that accurate load-calculation procedures, as Burdick [10] emphasizes, are designed to address.

The near-absence of integrated economic analysis compounds these effects. With 50.0% of design engineers calculating neither CAPEX nor OPEX, and a further 11.1% calculating only one of the two, 61.1% of designs proceed without a complete economic framing. In such a framing vacuum, oversized solutions are difficult to challenge, and downstream operating costs cannot be weighed against initial savings.

4.2 The design–installation coordination gap

The findings reveal a bidirectional coordination failure between the design and installation stages. From the installation side, 92.9% of engineers reported that equipment space is not allocated in the design and 71.4% that the design does not correspond to actual on-site conditions. From the design side, 50.0% of engineers cited the inability to collaborate with installation engineers as a principal challenge. The symmetry of these complaints points to a structural rather than an individual problem: the two stages are treated as sequential hand-offs rather than as integrated phases, with minimal feedback from installation experience flowing back into design practice.

This structural separation also helps explain the persistence of simplified methods at the design stage. Fully specified, physically based procedures such as those in the ASHRAE Handbook [7] and ISO 52016-1 [8] presuppose iterative coordination around spatial, mechanical, and thermal constraints; where that coordination is absent, lower-coordination methods tend to dominate by default. Improving calculation methodology and improving inter-stage coordination are therefore not independent objectives — progress on each enables progress on the other.

4.3 The "installed-but-unused" phenomenon

Among the most striking findings is that only 25.0% of operating systems run at full design capacity, while 62.5% are partially operational and 12.5% are switched off altogether. Combined with the finding that monthly electricity costs exceed MNT 5 million for 75.0% of respondents, this indicates that substantial capital has been committed to systems that are not delivering their intended performance. Two proximate mechanisms emerge from the data: control-panel malfunctions (62.5%) and repairs delayed by the absence of qualified technicians (50.0%). A deeper driver, however, lies in workforce and documentation capacity: 92.9% of installation engineers identified a shortage of trained operations personnel, 64.3% reported insufficient knowledge of system configuration, and 42.9% cited the absence of Mongolian-language operation manuals.

This operational pattern cannot be understood in isolation from the design stage. When integrated CAPEX–OPEX analysis is not presented to the client, the life-cycle implications of complex systems are not surfaced at the decision point, and the training and documentation infrastructure required to sustain those systems is not planned for. The "installed-but-unused" outcome thus emerges as the downstream consequence of upstream methodological and economic gaps rather than as an independent operational failure. That design engineers themselves ranked insufficient operational knowledge alongside electricity costs as the most critical sector issue — each cited by 27.8% (5/18) — suggests that this causal link is at least partially recognized across the professional groups, even if it is not yet reflected in design-stage practice.

4.4 Climate adaptation and the case for a national platform

Mongolia's climatic context amplifies the cost of the preceding gaps. The urban heat-island intensity documented by Ganbat et al. [5] — an annual mean of 1.6 °C rising to a daily maximum of 4.3 °C — is not captured by generic W/m² coefficients, nor is it represented in the default weather inputs of most internationally distributed calculation tools. Conversely, the same extreme continental regime produces cool summer nights that 66.7% of respondents regard as offering at least partial scope for passive cooling — an opportunity that simplified methods cannot exploit systematically.

Against this background, the 91.7% endorsement of a dedicated national cooling code (among the 12 respondents to that item) and the 90.0% overall interest in a brand-neutral calculation platform are mutually consistent rather than incidental findings: they express a sector-level recognition that locally adapted tools are required to translate the physical rigor of the ASHRAE Handbook [7] and ISO 52016-1 [8] — and the minimum energy-performance requirements of ASHRAE Standard 90.1 [9] — into methods usable under Mongolian conditions. The unanimous support for such a platform among installation engineers (100%, 14/14) is particularly instructive. This group is the most directly exposed to the coordination failure discussed above in "The design–installation coordination gap," and their uniform endorsement suggests that a shared calculation platform — by embedding consistent assumptions accessible to both design and installation teams — would function as a coordination mechanism as well as a technical tool.

In the broader energy context projected by the IEA [6], in which global cooling energy demand is expected to triple by 2050, the cost of inaction scales with demand. A platform grounded in Mongolian climate data, aligned with the physical procedures of the ASHRAE Handbook [7] and ISO 52016-1 [8], and consistent with the minimum energy-performance requirements of ASHRAE Standard 90.1 [9], therefore addresses both an immediate sectoral need and a longer-term sustainability imperative.

4.5 Limitations

Several limitations should be acknowledged. First, although the sample was demographically weighted toward experienced practitioners — 87.5% of respondents had more than five years of practice — the overall size ($n = 40$) is modest, and the use of purposive rather than probabilistic sampling limits statistical generalization. Second, the two closing questions on regulatory codes and passive cooling were introduced during the study and were answered by only 12 respondents; the weight placed on those specific findings should be adjusted accordingly. Third, all responses are self-reported and therefore subject to the usual risks of social-desirability and recall bias. Finally, the study is cross-sectional and specific to Mongolia; comparable surveys in other high-altitude, cold-continental settings would help establish whether the patterns observed here are regionally characteristic or specific to the Ulaanbaatar combination of urban heat-island exposure, extreme continental climate, and rapid glass-façade adoption.

5 Conclusions and recommendations

This study identified three principal challenges facing Mongolia's building cooling sector.

First, design-stage practice is dominated by an experience-based rule-of-thumb (W/m^2) sizing approach (88.9%) that makes insufficient use of Mongolian climate data and cannot represent the physical processes governing cooling demand. Economic framing is equally weak: 50.0% of design engineers calculate neither CAPEX nor OPEX, and a further 11.1% calculate only one of the two. As a consequence, capacity oversizing is observed in 38.9% of cases, driven predominantly by experience-based judgment (71.4%) and excessive safety factors (57.1%) rather than by external pressures. In the absence of an integrated economic rationale presented to clients, installed systems are in some instances not fully utilized and are switched off, producing adverse downstream outcomes including degraded indoor air quality, reduced occupant comfort, and lower productivity.

Second, coordination between the design and installation stages is structurally weak. 92.9% of installation engineers reported that space for equipment placement is not allocated in the design, and 71.4% that the design does not correspond to actual on-site installation conditions. The symmetry of these complaints with design engineers' own concern about inadequate collaboration (50.0%) indicates that the problem is systemic rather than individual, pointing to the need to transition toward a BIM-based integrated design approach.

Third, the operation stage is in particularly poor condition. Only 25.0% of operation engineers reported that their systems are fully operational, while 62.5% are partially operational and 12.5% are switched off and out of service. The most widespread causes of failure were control-panel malfunctions (62.5%) and repairs delayed by the absence of qualified technicians (50.0%). At a deeper level, 92.9% of installation engineers identified a shortage of trained operations personnel, 64.3% cited insufficient knowledge of system configuration, and 42.9% reported the absence of Mongolian-language operation manuals. These findings indicate a need to integrate hands-on operational training into the university programs that prepare HVAC specialists, to establish continuous professional development for practicing specialists, and to make technical documentation in the Mongolian language widely accessible.

On the basis of these findings, the following recommendations are proposed:

1. **Amend BNbD 41-01-11** to include a dedicated cooling-load calculation section adapted to Mongolian climatic conditions — supported by 91.7% of respondents to the relevant item.
2. **Develop and deploy coolcalc.mn** as a brand-neutral calculation platform offering a complete methodology in Mongolian, aligned with the physical procedures of the ASHRAE Handbook — Fundamentals [7] and ISO 52016-1:2017 [8] and consistent with the minimum energy-performance requirements of ASHRAE Standard 90.1 [9], and providing integrated CAPEX–OPEX analysis — supported by 90.0% of all respondents.
3. **Drawing on the finding that insufficient operational knowledge was ranked as the sector's leading issue (32.5%)**, deepen the practical components of operation, maintenance, and commissioning within the curricula of universities that train specialists for the building cooling field.
4. **Incorporate passive (free) cooling strategies** into design engineering decisions in order to exploit Mongolia's climatic potential, reduce the energy consumption and environmental impact of cooling systems, and improve the efficiency of capital investment. Further research should implement pilot projects in real buildings and measure and validate their outcomes. The potential role of intelligent control systems, though not directly addressed by this survey, merits investigation in future work.

Further work is required to pilot the coolcalc.mn platform in real buildings and to validate its calculation results against established international procedures [7]–[9].

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