

Powering Progress: Energy Storage Systems in Singapore's Built Environment

From Construction to Operation

An Industry Report by
Infinity Cube, the Energy Studies
Institute, and the Singapore
Green Building Council





TABLE OF CONTENTS

2	.....	Executive Summary & Key Recommendations
4	.....	Introduction – BESS for Singapore’s Built Environment
8	.....	The BESS Landscape – Technology, Applications & Readiness
12	.....	The Business Case: Costs, Value & Financing
14	.....	Rental or Energy Storage-as-a-Service Models
14	.....	Direct Purchase Model
15	.....	Hybrid BESS power configuration and economic benefits
16	.....	Environmental and Strategic Benefits
17	.....	Considerations and Recommendations for Commercial Viability
20	.....	Mobile BESS for Construction: A Practical Guide
29	.....	Singapore Case Studies (Qualitative & Quantitative)
33	.....	Strategic Roadmap & Future Outlook
I	.....	References

EXECUTIVE SUMMARY

As Singapore's built environment accelerates its push toward whole-lifecycle sustainability, transitioning away from legacy, diesel-reliant energy management is critical. This report explores the deployment of Mobile Battery Energy Storage Systems (BESS) as a transformative solution for decarbonising temporary construction and production sites.

While conventional diesel generation remains the default, it incurs severe penalties in carbon emissions, operational inefficiency, and financial overhead through generator oversizing. Integrating mobile BESS, particularly utilising inherently stable **Lithium Iron Phosphate (LFP) chemistry** paired with advanced **Battery Thermal Management Systems (BTMS)** and **Energy Management Systems (EMS)**, slashes diesel consumption by 20% to 80%, eliminates peak load stress, and dramatically cuts net operational costs.

Empirical evidence from local deployments confirms this massive commercial and environmental value proposition:

Temporary Construction Sites

(Kimly Construction): Decoupling power generation from erratic peak-load machinery (such as tower cranes) eliminated inefficient generator idling, delivering an 46.8% reduction in LCOE alongside a 67.2% slash in diesel consumption and carbon emissions.

Long-Term Batching Facilities (Pan-United):

Leveraging a mobile BESS for advanced load smoothing bridged a critical grid deficit—allowing the plant to operate within a capped 400 A grid connection despite 826 A peak demands—and unlocked a 67.0% reduction in LCOE and a 69.8% reduction in emissions by entirely eliminating diesel generation.



KEY RECOMMENDATIONS

Successfully deploying mobile BESS requires;

- Navigating established regulatory pillars
- Encompassing grid interconnection (SS 650)
- Environmental standards (TR 77)
- Local licensing via LEWs and QPs
- SCDF fire safety guidelines

All while overcoming market friction such as upfront cost perceptions and technical unfamiliarity. To bridge these gaps and scale adoption across the built environment value chain, key strategic recommendations include:

For Regulators and Policymakers:

Expanding existing stationary storage frameworks into dedicated practical advisory codes for mobile BESS and deploying targeted public co-funding mechanisms—such as expanded built environment technology grants—to lower initial acquisition barriers and encourage early-stage leasing.

For Developers and Main Contractors:

Engaging with BESS providers early during pre-tender and mobilisation stages, conducting collaborative virtual prototyping, and documenting integration outcomes to establish empirical risk-mitigation benchmarks.





INTRODUCTION

BESS FOR SINGAPORE'S BUILT ENVIRONMENT

As the global climate crisis intensifies, carbon-intensive industries are facing increased scrutiny. In line with long-term plans to reach net-zero emissions by 2050 (National Climate Change Secretariat 2020), Singapore has pledged to reduce carbon emissions to 60 MtCO₂e by 2030 (National Climate Change Secretariat 2021), with plans to (National Climate Change Secretariat 2020) reduce emissions by an additional 10-15 MtCO₂e by 2035 (National Climate Change Secretariat 2025). Recognising the significant contribution of the built environment to national emissions, Singapore Green Building Master Plan (SGMP) sets clear decarbonisation targets for the sector, which accounted for more than 20% of national carbon emissions in 2019 (BCA and SGBC 2021). Under the 80-80-80 by 2030 target, Singapore has set up ambitious decarbonisation goals, mandating:

- 80% green buildings,
- 80% super low energy new developments,
- and 80% energy efficiency improvements (compared to 2005) by 2030.

Complementing these decarbonisation efforts, the Green Mark 2021 framework introduced a dedicated Whole Life Carbon section, enabling developers to earn points through the assessment and reduction of carbon impacts across the building lifecycle. This reflects Singapore's growing emphasis on quantifying and managing carbon impacts beyond operational energy use and highlights the increasing importance of life cycle-based carbon assessment in the built environment.

A whole-life perspective is particularly important as carbon emissions from the built environment arise across multiple life cycle stages, including material production, construction activities, building operations, and end-of-life processes. While the production of construction materials often represents the largest share of lifecycle carbon emissions, these emissions are largely influenced by upstream manufacturing processes and supply chain decisions. In contrast, emissions associated with operations and construction activities are more directly within the control of project stakeholders, creating immediate opportunities for decarbonisation through improved site and energy management.



Figure 1: Use cases for BESS across the built environment.

Battery Energy Storage Systems (BESS) have emerged as a promising solution for optimising energy efficiency and operational costs. During the operational phase, BESS has proven successful in applications such as improving port energy performance at PSA’s Pasir Panjang Terminal (PSA Singapore 2022) and enabling ultra-fast charging at Huawei and SP Group’s Temasek Polytechnic EV station (SP Group 2026).

This report focuses specifically on the application of BESS within the construction sector, and its offerings for substantial operational cost and energy optimisations. Historically, construction sites have exhibited highly variable power demand profiles characterised by intermittent peaks from heavy machinery like tower cranes, hoists, and concrete pumps. To ensure grid stability or accommodate off-grid setups, contractors traditionally deploy diesel generators sized for anticipated peak loads. Consequently, these generators run at low load factors for extended periods, leading to poor fuel efficiency, excessive fuel consumption, and unnecessary greenhouse gas emissions (Electrical Trader 2025).

The integration of BESS improves the fuel efficiency of diesel generators by acting as a load leveller, storing energy during low-demand periods and discharging during peak events. This enables contractors to size generators closer to average demand rather than peak demand. Operating generators continuously nearer their rated capacities improves fuel efficiency, reduces fuel consumption, lowers operational costs, and cuts emissions. The use of BESS as a load leveller to address intermittency is not new and has been widely implemented for both renewable and non-renewable energy sources, and for isolated grids. For intermittent renewable energy sources, BESS has shown -

successful implementation with solar and wind for the provision of utility scale and micro-grid power (Ma et al. 2014; Lehtola 2024; Simshauser 2025). Similarly, BESS has been integrated into hybrid renewable-diesel energy systems to supply power to remote areas and isolated grids across Cameroon and Saudi Arabia amongst other countries (Rehman and Al-Hadhrami 2010; Olatomiwa et al. 2015; Rodríguez-Gallegos et al. 2018; Khalid et al. 2021; Amoussou et al. 2024).

In the construction sector, the hybrid BESS-diesel-grid setup has been introduced and demonstrated practical benefits, through mobile BESS solutions deployed by Infinity Cube across Land Transport Authority (LTA), Housing & Development Board (HDB), and private residential projects (Infinity Cube 2025a, b, c). These projects achieved annual diesel savings of 56,000 to 289,000 litres—representing a 67% to 100% reduction compared to conventional generator setups—and generated estimated annual cost savings between SGD 73,000 and SGD 375,000.

Beyond direct financial savings, mobile BESS integration helps developers and contractors align with corporate and statutory sustainability targets. Cutting diesel consumption directly reduces Scope 1 emissions for contractors and Scope 3 emissions for developers under the Science Based Targets initiative (SBTi). Furthermore, BESS deployment contributes toward points under the Whole Life Carbon (Cn) criteria of BCA's Green Mark 2021 scheme (Green Mark Department 2023), as well as credits under the Building Life-Cycle Impact Reduction and Innovation categories within the Leadership in Energy and Environmental Design (LEED) framework (USGBC 2026).

Despite the clear economic and environmental value proposition of BESS in construction, adoption barriers remain—including technology selection, upfront capital costs, operational logistics, safety requirements, and regulatory compliance. This report provides a practical guide for developers and contractors seeking to deploy BESS in Singapore's construction sector. It covers available BESS technologies and applications, the governing regulatory and safety ecosystem, a Singapore-specific business case analysis, and actionable implementation pathways to support informed decision-making.



THE BESS LANDSCAPE

TECHNOLOGY, APPLICATIONS & READINESS

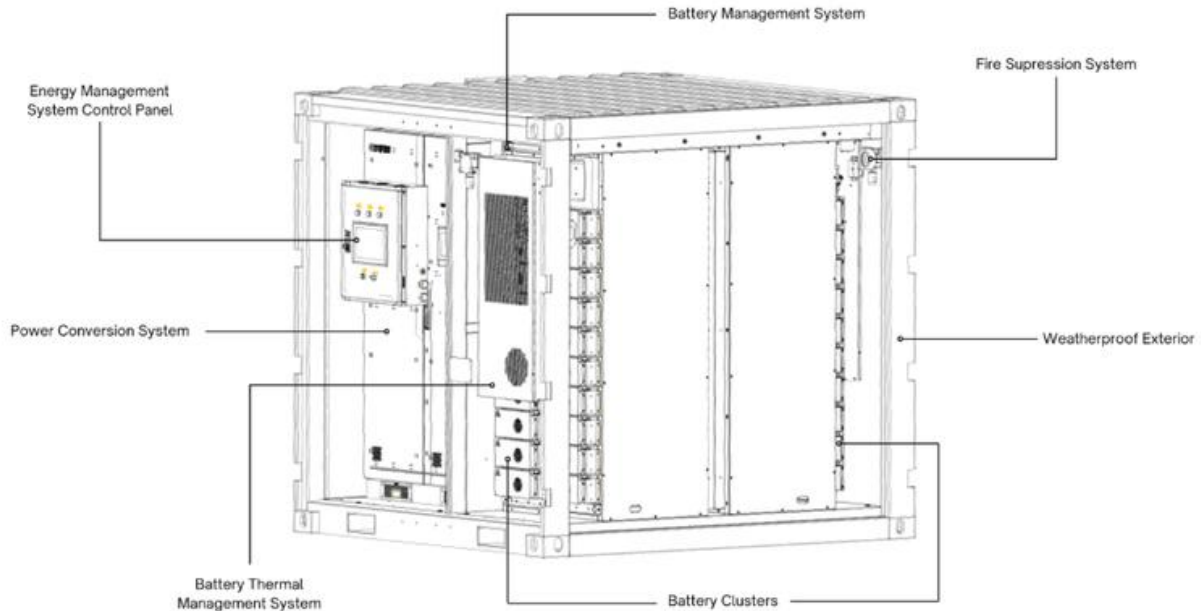


Figure 2: Core components of a typical BESS (Source: Infinity Cube).

A BESS relies on three integrated subsystems to manage, convert, and deliver electrical power (EMA 2020), as illustrated in Figure 2:

- The Battery System, which comprises battery cells arranged into clusters, together with a Battery Management System (BMS). The BMS monitors and controls key operating parameters such as temperature, voltage, current, and state of charge to ensure safe and reliable operation.
- The Power Conversion System (PCS), converts electricity between alternating current (AC) and direct current (DC), enabling energy transfer between the battery, electrical loads, and power sources.
- The Energy Management System (EMS) manages and optimises energy flows between the BESS, load and power sources.

Depending on energy capacity, BESS deployments are generally categorised into three key scales (Cumins Inc 2024), with each scale serving distance applications:

- Residential scale: below 30 kWh
- Commercial/Industrial scale: 30 kWh – 10 MWh,
- Utility/Grid scale: Above 10 MWh.

In the construction phase of the built environment, most deployments fall within the commercial/industrial category, where systems are used to support temporary site power, peak shaving, load levelling, and hybrid diesel-battery configurations.

Battery Chemistry	Energy Density	Cycle Life*	Use Cases
Lead Acid Batteries	30 – 50 kWh/kg	300 - 1500	Residential/Utility scale: Automotive power and stationary backup power.
Vanadium Redox Flow Batteries (VRFB)	20 – 33 kWh/m3	20,000+	Industrial/Utility scale: Industrial scale storage, and microgrids for remote locations.
Lithium Iron Phosphate (LFP)	170 kWh/kg	2,000 – 6,000	All scales: Standard range EVs, residential, industrial, and utility scale energy storage
Lithium Nickel Manganese Cobalt (NMC)	350 kWh/kg	800 – 2,000	All scales: Long range EVs, portable electronics, residential, industrial, and utility scale energy
Lithium Manganese Iron Phosphate (LMFP)	230 kWh/kg	2,000 – 3,000	Residential/ Utility scale: Long range EVs and industrial energy storage

Table 1: Overview of common battery chemistries.
Source: (Battlebury 1999; Suberu et al. 2014; Zhao 2023; ideona 2024; EV Lithium 2026b)

While commercial BESS span several battery chemistries (Table 1), lithium ion technologies continue to dominate the global market owing to their declining costs, high -

Note: * A battery’s cycle life is defined as the number of full discharge cycles required for its State of Health (SOH) to fall to 80% of original capacity.

energy density, and superior round-trip efficiencies (IEA 2024). In commercial, industrial and utility scale applications, Lithium Iron Phosphate (LFP) has emerged as the definitive technology, owing to its relatively low cost, long cycle life, and superior thermal stability compared to contemporary Li-ion chemistries such as NMC. Meanwhile, niche non-Li battery chemistries, such as lead-acid and vanadium redox flow batteries (VRFBs), have seen application in stationary storage and remote microgrids such as the 1 MWh Vflowtech VRFB installed in Pulau Ubin (EMA 2025b).

Looking ahead, LFP is projected to maintain its market dominance across construction and industrial BESS applications over the short to medium term (Sharma 2026b). However, its continued deployment requires careful consideration of environmental, social and governance (ESG) issues. Although LFP batteries generally avoid the use of cobalt and nickel, they remain dependent on lithium and other critical materials, whose extraction and processing can involve significant ESG trade-offs. Nevertheless, when assessed across their full life cycle, BESS can deliver net environmental and societal benefits over the longer term by supporting renewable energy integration, improving energy efficiency and reducing reliance on fossil-fuel-based generation. These benefits can be further strengthened through responsible mineral sourcing, improvements in battery durability and the development of effective reuse and recycling systems.

At present, emerging alternatives like sodium-ion and second-life batteries provide avenues to address these ESG. However, they face significant short-term commercial hurdles, due to the prevailing low price of first-life Li-ion batteries:

- Sodium-ion lacks supply chain maturity and high energy density (Lombardo et al. 2026).
- Second-life packs face prohibitive testing, repurposing, and recertification costs (Prenner et al. 2024).

As battery technologies, and recertification processes continue to mature, both Sodium-ion and 2nd life batteries present promising options for diversifying the BESS market. Furthermore, advancements in Li-ion battery technologies, such as the development of new lithium extraction techniques (Farahbakhsh et al. 2024), the elimination of cobalt and nickel in LFP batteries (Sharma 2026a), and the expansion of battery recycling facilities within Southeast Asia (Seah 2026), all present promising opportunities to reduce the ESG impact of BESS production.



THE BUSINESS CASE

COSTS, VALUE & FINANCING

As discussed in the introduction, the integration of mobile BESS into the construction sector has the potential to offer substantial benefits in both costs and carbon emissions. In case studies in Singapore presented in a future section, BESS integration in construction and batching operations show cost reduction of 46.8% - 67.0%, and emissions reduction of 67.2% - 69.8%. However, poor or inappropriate implementation has significant impacts, potentially squandering the economic and environmental benefits to be had.

In construction, BESS is seen as an alternative or complement to conventional diesel-based power solutions on project sites. Consequently, evaluating its business case hinges not on long-term building operations, but on how temporary energy is procured, managed, and optimised during the project delivery phase. The economic viability of onsite BESS deployments is project specific, and dependent on several key variables. In the following sections, an overview will be provided on how to evaluate the viability of BESS integration, including: BESS deployment models, methods to determine the financial benefit of deployment, and the non-monetary benefits of BESS integration. Commercially, BESS deployment falls into two categories (Figure 3): rental/service-based arrangement and direct ownership.

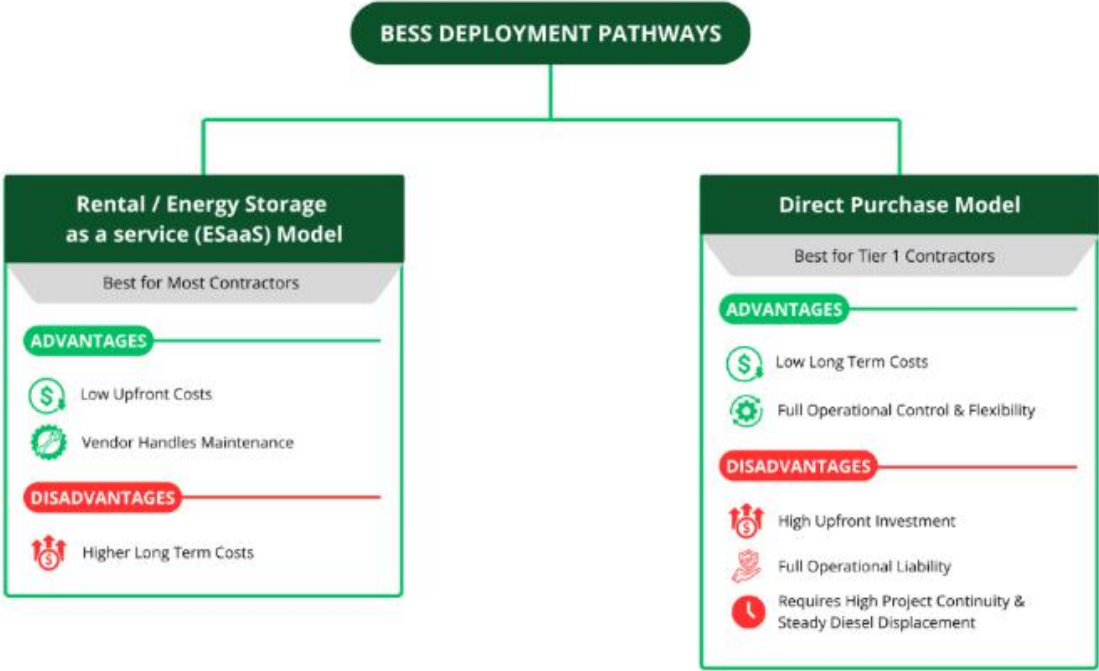


Figure 3: Characteristics of commercial BESS deployment models.

Rental or Energy Storage-as-a-Service Models

In Singapore, the majority of contractors use a Rental or Energy Storage-as-a-Service (ESaaS) model, due to the lower barriers of financial barriers of entry:

- Under a Rental model, contractors typically pay a fixed fee over a defined period for the use of the equipment, with limited performance obligations.
- Under an ESaaS model, BESS vendors structure energy storage as a service, managing system operation, and price their services based on energy usage, performance outcomes, or demonstrated savings.

The key advantage of these models is the elimination of operational overheads and large upfront costs. Because ownership remains with the provider, specialised servicing, safety compliance, and predictive maintenance falls under the vendor's scope, reducing technical capability requirements on the part of the contractors. Similarly, by leasing or contracting BESS services instead of directly purchasing them, high capital expenditure (CAPEX) requirements are exchanged for low operational expenditures (OPEX) in the form of rental/lease costs. Thus, allowing contractors to capture BESS efficiency gains without taking on long-term asset risk.

Direct Purchase Model

For established, Tier-one contractors, direct BESS purchase may be considered. In direct purchase arrangements, BESS units are wholly owned by contractors and are treated as a part of their equipment fleet. Subsequently, this arrangement comes with specific trade-offs and benefits.

- **Trade-Offs:** Direct purchase necessitates large upfront capital investments, significantly increasing financial long-term liabilities for the contractors. Furthermore, the continuous servicing, safety compliance and maintenance liabilities of BESS necessitate high technical capability from contractors.
- **Economic Benefit:** Direct ownership provides contractors with greater control over their site energy management strategies and equipment deployment decisions. Furthermore, assuming long term project continuity (2-4 years) and continuous BESS deployment, upfront BESS investment costs can be amortised, resulting in lower long-term costs compared to Rental/ESaaS models.

Hybrid BESS power configuration and economic benefits

The total financial viability of site power is evaluated using Total Cost of Ownership (TCO) and Levelised Cost of Energy (LCOE) framework, as detailed in Equations (1) and (2):

$$(1) \quad TCO = ACAPEX_{bat} + ACAPEX_{gen} + OPEX_{bat} + OPEX_{gen} + Fuel_{gen} + Cost_{grid} \\ + Cost_{maint} + Cost_{logistics}$$

$$(2) \quad LCOE = \frac{TCO}{E_{load}}$$

Traditionally, on-site power is provided through one of two baseline profiles:

- **Diesel-Only Configurations** featuring minimal upfront capital expense and large highly volatile operating expenditures (OPEX), driven by routine maintenance, continuous fuel consumption, and high engine inefficiencies due to highly fluctuating construction load profiles.
- **Grid-Only Configurations** featuring low operating costs and reduced localised emissions, constrained by a lack of deployment flexibility and constrained by site-specific supply limitations, connection lead times, and reduced flexibility in responding to high variable construction load.

Integrating modular BESS units creates a **Hybrid Power Configuration**. While adding BESS increases baseline equipment rental or capital cost, it substantially reduces overall OPEX through two operational mechanisms:

- **Peak-Shaving & Generator Resizing Levelling:** In many project sites, generators are severely oversized due to their need to service brief, heavy peak loads (e.g., tower crane starts), running significantly under capacity (< 30%) for the majority of their operation. As a result, this causes incomplete fuel combustion ("wet stacking") and excessive wear, significantly increasing fuel consumption, maintenance, and operating costs. BESS absorbs transient load spikes, allowing the generator to be downsized and continuously operated closer to its optimal point, Thus, reducing fuel consumption by 50% or more.
- **Power Quality & Grid Stability:** The rapid transient response of BESS dampens voltage sags and frequency fluctuations, protecting sensitive heavy equipment and minimising site downtime.

Real-world deployments demonstrate these financial advantages. In a superstructure project executed by Ampd Energy and Gammon Construction, replacing a 400 kVA standalone diesel generator with a 400 kVA BESS connected to a lower-capacity grid supply reduced operational expenditure by 78% and CO₂ emissions by 81% (Ampd Energy 2019). Locally, deployment of the EH-ONE+ BESS by GoRental Global achieved annual carbon savings of 223 tonnes while lowering total project power costs by 40% to 50% (Soh 2026).

Environmental and Strategic Benefits

Beyond direct fuel savings, BESS integration provides critical strategic alignment with Singapore's evolving decarbonisation mandates under the BCA Green Mark 2021 framework:

- **CO₂ Emissions Mitigation:** Burning one litre of diesel produces approximately 2.68 kg CO₂e. Displacing 56,000 to 289,000 litres of diesel annually as demonstrated in local deployment trials studies Infinity Cube (2025a, 2025b, 2025c), translates to an immediate avoidance of 150 to 775 tonnes of CO₂e per site.
- **Non-CO₂ Emissions management:** When generators operate at low load factors, diesel tends to burn incompletely, resulting in Carbon monoxide (CO) emissions and particulate matter (PM). In light of hazards associated with long- and short-term exposure, the National Environment Agency (NEA) sets emissions standards for construction site and other Off-Road Diesel Engines (ORDEs). Subsequently, improvements in fuel efficiency and operational capacity brought on by BESS, reduce fuel consumption and incomplete combustion to decrease the generation of such emission.
- **ESG & Scope Reduction:** Lower fuel burn directly reduces a contractor's Scope 1 emissions and a developer's Scope 3 construction footprint under corporate ESG reporting and Science Based Targets initiative (SBTi) commitments.
- **Future Financial Incentives:** The economic business case will continue to strengthen as local green financing instruments and government support schemes such as the Energy Efficiency Grant (EEG) available until March 2027 (gobusiness Singapore 2026), lower capital barriers, accelerating a structural shift toward low-carbon construction logistics.

Considerations and Recommendations for Commercial Viability

Overall, while the poor use of BESS may result in increased costs, careful planning and implementation of BESS into the construction sector allows for contractors to fully benefit both environmentally and economically. Key considerations when implementing BESS are as follows:

- **Deployment model, expertise and project period alignment:** Direct ownership requires contractor experience and requires long term usage for commercial viability. For contractors with less experience and shorter project durations, rental/ ESaaS models eliminate expertise and upfront capital barriers,
- **Right-sizing of BESS and generators:** BESS capacity and any associated generator should be selected with consideration of the intended use case, operating scenario and connection arrangement, rather than peak demand alone. Appropriate sizing can avoid the cost and underutilisation associated with over-sizing while reducing the operational risks associated with under-sizing. In hybrid configurations, BESS may also allow generators to be sized closer to representative site loads and operated more efficiently.
- **Regulatory & ESG Drivers:** As green financing instruments and BCA Green Mark requirements tighten, the non-monetary value of BESS (i.e. Scope 1/3 emissions reduction and Green Mark points) translates directly into competitive advantage and access to incentives.

As Li-ion batteries continue to fall in price, the cost of implementing mobile BESS into the construction sector is projected to decrease further, thus improving the economic use case. For contractors and developers still evaluating BESS, we recommend starting with a trial rental deployment on a medium-term project. This allows hands-on experience with minimal financial exposure, while generating site-specific data to inform future investment decisions.

NAVIGATING THE REGULATORY & SAFETY ECOSYSTEM

Mobile BESS offers significant benefits in reducing fuel consumption and improving energy efficiency, safety and regulatory compliance remain important considerations for contractors and developers evaluating deployment.



MODERN TECHNOLOGY REDUCES RISK

- Inherently stable LFP battery chemistry
- Advanced Battery Thermal Management Systems (BTMS)



Singapore maintains a comprehensive regulatory ecosystem that guides providers, contractors, and developers through safe lifecycle management.

THE DEPLOYMENT OF MOBILE BESS IN SINGAPORE CONSIDERS 4 KEY REGULATORY PILLARS



Figure 4: The regulatory pillars of mobile BESS deployment in Singapore.

While mobile BESS significantly reduces fuel consumption and boosts energy efficiency, safety and regulatory compliance remain top priorities for contractors and developers. Historic thermal runaway incidents, such as the 250 MW Gateway Energy Storage facility in California (Nikolewski 2024) or the recent Amp Clean Energy BESS fire in Exeter UK (Miles Devon 2026), still fuel public anxiety. However, modern deployments heavily mitigate these risks: the inherent thermal stability of Lithium Iron Phosphate (LFP) chemistry (EV Lithium 2026a), paired with advanced Battery Thermal Management Systems (BTMS), ensures robust operational safety.

Furthermore, Singapore formalises these safeguards through a comprehensive regulatory ecosystem guiding the safe lifecycle management of BESS. Where relevant to the proposed system and connection arrangement, reference may also be made to SS 725-1-1:2026, Electrical Energy Storage Systems – Part 1-1: Safety Considerations for Grid-Integrated EES Systems – General Specification. Deploying mobile BESS in Singapore requires consideration of four key regulatory pillars (Figure 4):

- Grid Interconnection (SS 650 part 1) – Contractors deploying temporary power setups must secure formal utility approval if they wish to use BESS and generator systems in parallel with grid power.

- Environmental & Operational Planning (TR-77-1 & TR-77-2) – Systems must be engineered to withstand local ambient stressors—including high temperatures, dust, and moisture—under both normal and extreme operational conditions.
- Licensing & Governance (EMA – Handbook for Energy Storage Systems) – Projects require a Licensed Electrical Worker (LEW) to oversee installation, inspection, and certification for the Electrical Installation License, alongside a Qualified Person (QP) to secure SCDF fire safety plan approval.
- Site Siting & Fire Protection (Code of Practice for Fire Precaution in Buildings) – Li-ion installations are subject to strict capacity limits (20 kWh threshold, 600 kWh maximum stored energy). Temporary setups must be positioned at ground level, adjacent to public roads and fire hydrants, enclosed by non-combustible fencing, and equipped with dedicated 55A fire hose reels/hydrants.

Note: Personnel safety is the highest priority. All actions should only be taken if safe to do so; otherwise evacuate and await SCDF response.



MOBILE BESS FOR CONSTRUCTION

A PRACTICAL GUIDE

The integration of mobile BESS has profound implications for the construction sector's energy consumption and carbon emissions. By smoothening load peaks and storing excess power, mobile BESS eliminates the need for generator oversizing, cuts diesel consumption by 20–80% and slashes runtime and maintenance requirements to drive down operating costs. However, it is not a “silver bullet” technology; suboptimal integration frequently results in limited effectiveness. This section outlines a structured, practical approach to mobile BESS integration to aid prospective contractors in achieving successful deployment, maximising value, and avoiding common implementation pitfalls.

Site Assessment and Logistical Planning

A key consideration for contractors is ensuring that both the BESS and any associated generator are appropriately sized. While over-sizing may provide a perceived operational buffer, it can lead to asset underutilisation and higher costs, particularly in rental-based models where system capacity influences pricing. Conversely, under-sizing may limit the system's ability to meet operational requirements.

An initial site assessment may therefore consider measured or representative load profiles, peak and average demand, equipment duty cycles and operating hours, starting or inrush currents, critical and non-critical loads, grid availability and connection limits, generator operating constraints, the proposed recharge strategy, and the required duration of autonomous operation. The relevance of these inputs will vary according to the use case and connection arrangement.

Logistical and deployment constraints are equally important to successful implementation. While most mobile BESS solutions are containerised, spatial planning should account for their physical footprint and applicable regulatory requirements. Practical considerations include equipment access, suitable ground conditions, cable routing, and maintenance and emergency access. Other site-specific considerations include drainage, ventilation, fire separation, security, earthing and protection from vehicle impact. These factors should be assessed alongside the physical footprint of the BESS and any associated generator or electrical equipment.

An assessment of two site configurations illustrates that BESS adoption does not necessarily reduce the overall spatial requirement. Based on assumed clearance distances of 1.5 m for each genset and 3 m for each BESS unit, the required footprint for one configuration increased from 76.6 m² for three gensets to 91.3 m² for two medium-sized BESS units, representing an increase of approximately 19%. In contrast, the footprint for another configuration decreased from 195.3 m² for nine gensets to 144.5 m² for a hybrid system comprising two large BESS units and two smaller gensets, representing a reduction of approximately 26%. These findings demonstrate that the spatial implications of BESS deployment are site- and configuration-specific and should be evaluated during the initial planning stage.

Similarly, for plants looking to adopt grid-connected or hybrid BESS configurations, early engagement with the Singapore Power Grid (SPPG) is critical to secure early approval for parallel BESS and grid operation. Under Singapore Standard SS 650 Part 1, prospective contractors should engage with their BESS provider and a Licensed Electrical Worker (LEW) to prepare the technical documents for CS1 (Consultation)/CS2 (Application) submission.

When developing project schedules including grid connected and hybrid BESS solutions, contractors are advised to factor a 4-8 week lead time for SPPG review. Furthermore, contractors are advised to consider their projected BESS charging schedules, and their impacts on local grid stress for CS1/CS2 submission. This is particularly critical for sites in areas with heavy residential electricity demand, where grid peak typically occurs at night—coinciding with the period when BESS units are most likely to be recharged after a day of construction activity. Contractors should factor this into their CS1/CS2 submissions and consider programming charging schedules to avoid exacerbating local grid stress.

Fire Safety & Worker Training Plan

Additional contractor responsibilities:

- Organising BESS fire safety modules and refresher: Include lessons on BESS warning signs (as outlined in Table 2) into worker site inductions and conduct regular training refreshers.
- Emergency drills: Conduct periodic fire drills simulating BESS thermal events to refresh emergency protocols (as outlined in Table 3).
- Signage: Place clear, multilingual signage around the BESS unit indicating emergency contact numbers, exclusion zone boundaries, and extinguisher locations.
- BESS provider coordination: Ensure the BESS vendor provides site-specific emergency response documentation and 24/7 technical support contact.

Warning Sign	Indicators	Action
Abnormal Odours	Sweet, acrid, or "chemical" smell emanating from the unit.	Immediately alert site supervisor; avoid prolonged exposure.
Unusual Sounds	Hissing, popping, or bubbling from within the enclosure.	Evacuate immediate area; contact BESS provider.
Visual Indicators	Swelling, bulging, or deformation of enclosure panels; visible smoke or	Initiate emergency protocol; call SCDF immediately.
BMS Alarms	Repeated or escalating BMS alerts (temperature, voltage, or current deviations).	Investigate immediately; do not reset without technical assessment.
Excessive Heat	Noticeable heat radiating from the unit beyond normal warmth	Shut down system if safe to do so; contact technical support

Table 2: BESS warning signs, indicators, and actions.

Step	Action
Evacuate	Clear all personnel from the immediate vicinity (minimum 30m exclusion zone).
Activate Alarm	Sound site emergency alarm; notify all workers.
Call SCDF	Dial 995 immediately. Do not attempt to fight the fire alone.
Do Not Use Water	Water can react with battery chemicals. Use Class D extinguishers (dry powder/sand) only if trained and safe to do so.
Isolate Power	If safe to do so, disconnect the BESS from all power sources (grid and generators).
Post-Event	Do not re-enter until SCDF declares safety. Maintain 24-hour monitoring watch—lithium-ion fires can reignite hours or days later.

Table 3: Emergency response protocol for BESS thermal event.

As discussed, modern LFP-based BESS units are inherently more thermally stable than other lithium-ion chemistries. However, the consequences of a thermal runaway event can be more persistent and challenging to manage than a conventional diesel generator fire, due to the possibility of BESS reignition following initial suppression, and their ability to produce toxic and flammable gases.

In addition to general regulatory compliance, site-specific fire-safety planning may consider available thermal-runaway test evidence, gas detection and ventilation, emergency isolation, fire separation, emergency access and response arrangements, and the management of firewater or contaminated runoff, where relevant to the system and site configuration.

As presented in Table 3, these may include organising fire-safety training and refreshers, educating workers on BESS warning signs, conducting emergency drills, coordinating with BESS vendors and installing appropriate signage.

Mobile BESS Operation and Synchronisation

Mobile BESS integration with existing power infrastructure, such as diesel generator sets and grid connections, requires appropriate coordination to support safe and stable operation. One important engineering consideration is the synchronisation of the BESS with adjacent generators. Incorrect integration may result in reverse power flow, where energy is inadvertently fed back into the generator, potentially causing equipment stress, accelerated engine wear or operational disruption.

Depending on the system configuration, reverse-power risk may be managed through appropriate generator protection settings, synchronisation controls, interlocks, anti-islanding or export-limitation functions, and coordination between generator and BESS control modes. These arrangements should be reviewed and tested as part of system commissioning.

Digitalisation via Energy Management Systems (EMS)

Beyond immediate logistical and operational factors, advanced system deployment leverages digitalisation to drive ongoing performance improvements. Modern mobile BESS architectures are increasingly integrated with advanced Energy Management Systems (EMS) that enhance functionality through real-time power system monitoring and control. Where connected to cloud-based platforms, operational data can be transmitted for remote monitoring, analysis and reporting, enabling the digitalisation of power-system management across project sites.

These digital platforms allow contractors to track energy use, optimise system performance and respond dynamically to operational changes without requiring constant on-site supervision. Depending on the system's complexity, EMS functions may include dispatch optimisation, State of Charge (SOC) management, generator start-stop optimisation, load prioritisation, alarms, event logging and remote monitoring. These capabilities can also support data-driven maintenance planning and the identification of operational performance issues.

To support green tender requirements and corporate ESG reporting, EMS capabilities may also facilitate the monitoring and reporting of energy use, fuel savings and associated emissions reductions. Where relevant, supplementary performance indicators such as system availability, round-trip efficiency, State of Charge (SOC) and -

State of Health (SOH) may provide further context on system performance. Clearly defining the reporting baseline, calculation assumptions and monitoring period can also improve the transparency and comparability of reported savings.

Strategic Vendor Selection Criteria

Finally, to fully realise the operational and environmental benefits associated with mobile BESS deployment, careful vendor selection is important. Experienced providers can deliver supporting engineering services, including upfront load profiling, generator synchronisation testing, commissioning, EMS monitoring, maintenance and site-specific emergency response support. These services can help bridge the capability gap for contractors lacking specialist internal resources.

In addition to hardware specifications and cost, vendor selection may consider applicable standards and safety certifications, asset reliability, thermal management and fire-safety features, commissioning capability, performance reporting arrangements, maintenance responsibilities and local technical support.

Project Documentation and Responsibilities

Depending on the scale, complexity and connection arrangement of the project, supporting documentation may include a temporary power strategy, BESS method statement, risk assessment, protection and control philosophy, commissioning records, operating procedures and emergency response plan. Responsibilities for system operation, maintenance, regulatory approvals, insurance and performance reporting should also be clarified among the relevant parties before deployment.

Implementation Pathways

The transition toward widespread adoption of Battery Energy Storage Systems (BESS) in Singapore's built environment requires coordinated action across the project lifecycle. Developers and contractors play distinct but complementary roles in embedding energy storage solutions into both the construction and operational phases.

The Role of Developers: Setting Project Direction

Developers shape strategic direction early in the project lifecycle by integrating BESS considerations directly into initial project planning and design briefs. Key responsibilities include:

- **Setting Targets:** Establishing definitive low-carbon construction targets.
- **Specifying Clean Tech:** Mandating the use of cleaner energy alternatives during the construction phase.
- **Framework Alignment:** Aligning project outcomes with Singapore's BCA Green Mark certification requirements, broader corporate Environmental, Social, and Governance (ESG) objectives, and global initiatives like those led by the World Green Building Council.

This proactive approach reflects a shift toward whole-lifecycle sustainability, where a building's environmental impact is mitigated during its construction phase, not just its operational lifetime.

The Role of Contractors: Project Strategy Implementation

Contractors are responsible for translating these strategic intentions into on-site execution by integrating BESS across three core phases:

- **The Tender Stage:** Contractors should evaluate site energy requirements early, comparing BESS-enabled hybrid solutions against conventional diesel-based approaches to balance cost, performance, and carbon footprints.
- **Procurement:** Tender specifications should define the principal BESS parameters relevant to the project, including power and usable energy capacity, applicable safety standards, monitoring requirements and the scope of vendor support. Where relevant, performance indicators such as system availability and round-trip efficiency may also be specified. Early engagement with solution providers can help ensure that the proposed system is appropriately sized for the anticipated site loads and operating conditions.
- **Deployment and Site Management:** Once deployed, contractors should focus on operational optimisation. This includes managing hybrid configurations, monitoring system performance and tracking indicators such as fuel savings, emissions reductions and operational efficiency, where the necessary data are available.

Overcoming Market Barriers Through Phased Adoption

Despite clear operational advantages, widespread BESS adoption faces market friction. Upfront expenditure perceptions often overshadow total lifecycle value, and a general lack of technical familiarity can fuel lingering safety and reliability concerns.

Addressing these challenges requires a combination of targeted industry education, localised demonstration projects, and transparent communication of proven case studies to build cross-sector confidence. To mitigate risk and smooth this transition, stakeholders should adopt a phased deployment pathway:

- **Phase 1: Hybrid Integration:** Initial deployments should utilise hybrid configurations that complement existing diesel generators. This allows site teams to gain hands-on operational experience while maintaining a traditional energy safety net.
- **Phase 2: Expanded Load Share:** As technical familiarity and confidence grow, the role of BESS can be expanded to absorb a larger share of the primary energy demand, integrating directly with on-site renewable sources like solar photovoltaics.
- **Phase 3: Full Electrification:** Ultimately, this maturation pathway leads to fully electrified, low- or zero-emission construction sites.

The pace and commercial model of progression may differ according to contractor capability and project pipeline. Tier 1 contractors with recurring projects and internal engineering resources may be better positioned to purchase BESS assets or develop in-house operating capabilities. Smaller contractors may initially benefit from rental or ESaaS arrangements in which the provider offers greater support for system sizing, operation, maintenance and performance reporting. The phased pathway can therefore be adapted according to project duration, technical capability and expected frequency of asset utilisation.

The successful implementation of BESS depends on early planning, cross-stakeholder collaboration, and a willingness to pivot away from legacy energy management frameworks. As the technology matures and local reference cases multiply, BESS is well-positioned to transition from a novel alternative to a standardised component of sustainable construction and building operations in Singapore.

A photograph of the Merlion statue in Singapore, with water spraying from its mouth. In the background, several modern skyscrapers are visible, including the UBS, ANZ, and HSBC buildings. The sky is blue with some clouds. A green graphic overlay is on the right side of the image, featuring a large green letter 'B' and three smaller rectangular images showing different views of the Merlion statue and the surrounding area.

SINGAPORE CASE STUDIES

QUALITATIVE & QUANTITATIVE CASE STUDIES

To demonstrate the commercial viability, this section evaluates two distinct case studies: A short-term temporary construction site, and a long-term batching site in Singapore. Table 4 provides a comparative overview of operational costs, fuel consumption, and environmental impacts between conventional diesel and hybrid energy configurations.

Case Study 1 : Kimly Construction - Public Housing Project

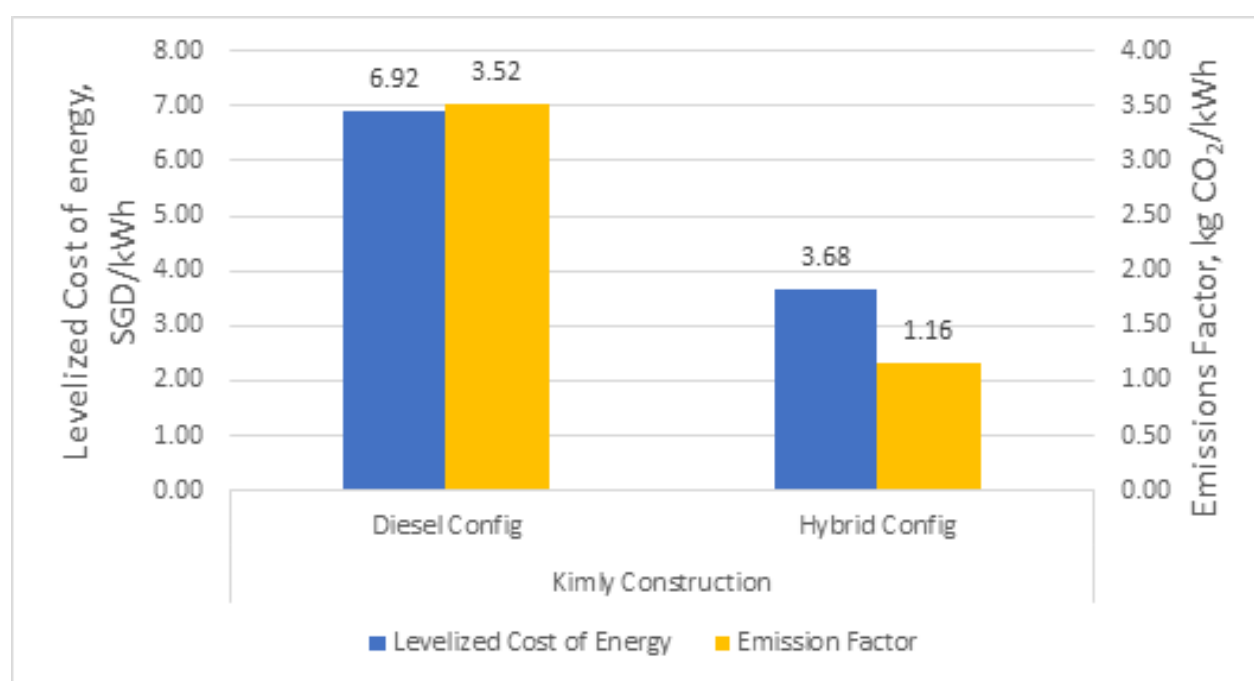


Figure 5: Levelized cost of energy and grid emissions factors for Kimly Construction – Public Housing Project.

In the first case study, a short-term temporary construction site utilising a traditional standalone diesel setup suffers from severe operational inefficiencies and financial penalties, registering an inflated LCOE of 6.92 SGD/kWh alongside an emissions factor of 3.52 kg CO₂/kWh (Figure 5). This inefficiency stems directly from the erratic load profiles of heavy machinery like tower cranes, which demand high peak loads during initial lifts followed by low prolonged loads during slewing and trolleying. Sizing traditional generators for these brief peaks forces them to run at severely inefficient, low-load factors, drastically inflating operational expenditure, fuel waste, and maintenance overhead.

Project Metrics	Case study 1 - Construction Site		Case study 2 - Batching plant	
	Kimly Construction – Public Housing Project (1 month data)		Pan-United – Concrete Batching Plant (3 months data)	
	Diesel Config	Hybrid Config	Diesel Config	Grid Config
Operational Data				
Total energy demand (kWh)	10,100		95,400	
Diesel consumption (l)	11,300	3,700	44,600	-
Grid power (kWh)	-	-	-	106,000
Financial Performance (SGD)				
Total Cost	111,500	77,800	161,200	55,500
Lease Cost (% Total)	9.84%	44.20%	9.31%	48.50%
Operating cost (% Total)	15.00%	9.29%	0.00%	8.75%
Fuel Cost (% Total)	75.10%	46.50%	90.70%	-
Grid Cost (% Total)	-	-	-	42.80%
Carbon Footprint (kg CO2)				
Diesel Emissions ^a	35,700	11,700	141,000	-
Grid Power Emissions ^b	-	-	-	42,600
Total Emissions	35,700	11,700	141,000	42,600

Table 4: Project metrics for Kimly Construction and Pan-United case studies across a Diesel only and Hybrid configuration.

a : Emissions from diesel usage are taken to be the well-to-wheel figure of 3.17 kg CO2 per litre (Carbon+alt+delete 2026)

b : Emissions from grid electricity use is computed from EMA's grid emissions factor of 0.402 kg CO2 per kWh (EMA 2025a)

Integrating a mobile BESS fundamentally transforms the commercial economics by decoupling power generation from real-time asset usage. Rather than forcing generators to idle continuously, the battery absorbs peak demands while the generator operates only at optimal, high-efficiency capacities or shuts down entirely. For Kimly Construction, this strategic deployment delivered a profound commercial and environmental return: a direct and substantial 46.8% reduction in LCOE, alongside a 67.1% slash in diesel consumption and carbon emissions.

Case Study 2 : Pan-United - Batching Plant

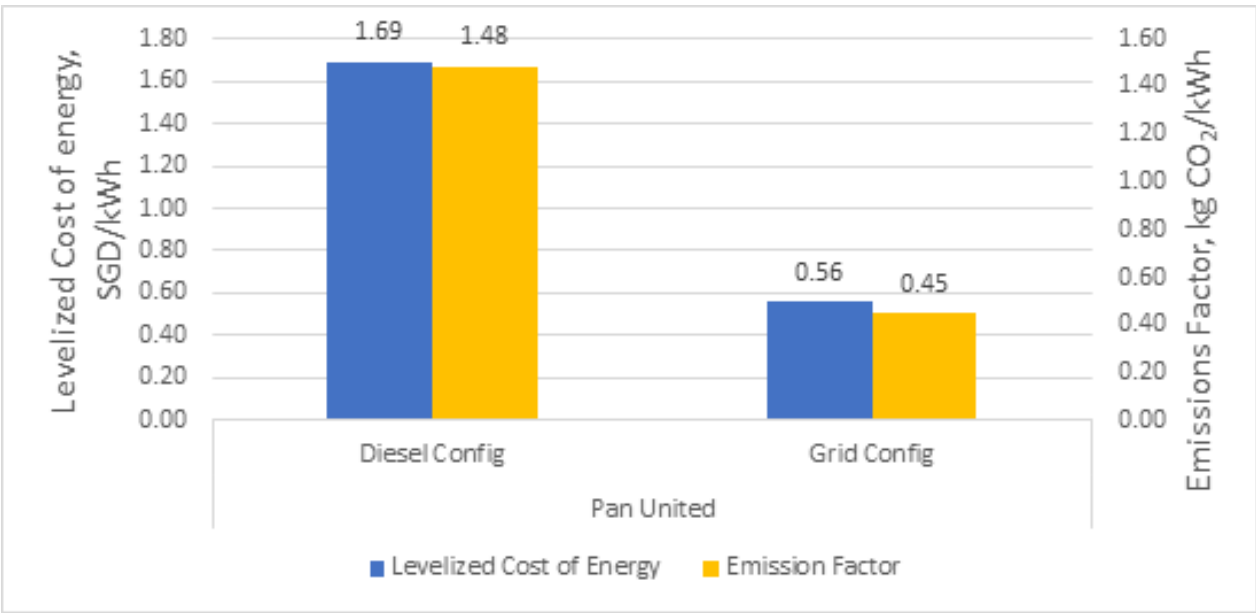


Figure 6: Levelized cost of energy and grid emissions factors for Pan-United – Batching Plant.

In the second case study, featuring a longer-term integration into a batching plant, the introduction of a mobile BESS drives dramatic commercial and operational breakthroughs by entirely eliminating on-site diesel generation (Figure 6). In the baseline scenario, Pan-United relied exclusively on diesel generators to power its concrete batching operations. Although grid power was physically available on-site, it was strictly capped at a maximum current of 400 A and were thus insufficient to meet the upper bound current requirements of daily batching activities which peak at 826 A. This capacity deficit previously locked Pan-United out of cheaper grid electricity, forcing reliance on expensive, carbon-heavy diesel fuel.

Integrating a mobile BESS unlocked the site's economic potential through advanced load smoothing: the battery absorbs peak demand spikes, allowing the facility to safely -

operate within the 400 A grid cap. By successfully pivoting from costly diesel generation to highly cost-effective grid electricity, Pan-United achieved a massive 67.0% reduction in LCOE alongside a 69.8% reduction in associated energy emissions.

Strategic Roadmap & Future Outlook

The value proposition of mobile Battery Energy Storage Systems (BESS) within the built environment is clear, as demonstrated throughout this report. However, the technology is fundamentally not a "one-size-fits-all" solution. The commercial viability and operational success of temporary BESS integration remain highly contingent upon project-specific variables, including project duration, construction scale, and peak energy demands.

Strategic roadmap for expanding mobile BESS integration

While modern mobile BESS solutions are engineered for rapid deployment, maximising their realised benefits depends heavily on meticulous early-stage planning, precise system sizing, and proactive load management. Inadequate foresight risks system underutilisation or sub-optimal configuration, which directly erodes the project's financial return. Furthermore, wider industry adoption faces systemic ecosystem hurdles. These including uncertainty and a lack of standardised advisory frameworks regarding the regulatory and safety matrix of temporary construction site BESS installations, and a familiarity gap amongst transitional contractors more accustomed to conventional diesel-based setups.

Delayed adoption could result in foregone opportunities to reduce fuel use and operating costs, demonstrate measurable sustainability outcomes and build familiarity with emerging energy-management capabilities. Contractors with limited BESS experience may also be less prepared to respond to future green tender requirements or provide project-level data on construction-phase energy use and emissions. Meanwhile, early adopters may continue to build capabilities in EMS integration, carbon reporting, dispatch optimisation and hybrid-system operation.

To bridge the existing technical and operational gaps and scale BESS adoption across the broader built environment value chain, a coordinated approach is required from both industry developers and public policymakers. For developers and main contractors, this involves engaging with BESS providers during the initial pre-tender and site mobilisation stages, collaborative virtual prototyping, and documenting integration outcomes to provide empirical benchmarks needed to mitigate risks.

Meanwhile for regulators and policy makers, existing stationary storage frameworks should be expanded to include dedicated practical advisory codes for mobile BESS. Furthermore, targeted public cofunding mechanisms (e.g. expanding the scope of built environment technology grants), can be used to lower initial expenditures associated with BESS to better promote early-stage leasing and acquisition.

Future outlook on battery storage technology

Looking across a 10-to-20-year horizon, the integration of energy storage within the built environment is expected to accelerate dramatically, driven by supply and demand side factors. Supply side factors affecting BESS integration into construction include continued declines in production costs, and the emergence of market disrupting battery technologies. Meanwhile demand side factors include the emergence of Industry 4.0, and the use of energy storage in smart building technology.

On the supply side, Li-ion batteries have seen an 85% reduction in production costs over the past decade (Orangi et al. 2024), driven by significant improvements in economies of scale and battery chemistries. As projected costs continue to decrease between 43.5% – 52.5% from 2020 – 2030 (Orangi et al. 2024), Li-ion batteries (specifically LFP) architectures are projected to maintain their dominant market share (Sharma 2026b). These cost reductions directly correspond with reduced financial barriers of entry for contractors and developers. Furthermore, as global supply chains mature and commercial scale is structurally proven, next-generation technologies such as Sodium-ion (Na-ion) are poised to act as market disruptors (Lombardo et al. 2026), providing alternate avenues for cost effective energy storage in the built environment.

Concurrently on the demand side, the convergence of the Internet of Things (IoT), edge and cloud computing, big data analytics, and Artificial Intelligence (AI) is increasingly reshaping energy asset management. In the construction phase, digitalisation, predictive maintenance, and smart energy monitoring have the potential to sharply reduce operational downtime and costs (Digi International 2024). Meanwhile in the operational phase, smart buildings are increasingly entering the market, with total energy consumption reductions of up to 35% made possible through AI-driven building management systems (Balcells 2024). Across both construction and operations, energy storage acts as the critical backbone for intelligent energy management (Priya and Senthil 2026), drastically enhancing building flexibility through automated load shifting and load smoothing.

Ultimately, the transition toward mobile Battery Energy Storage Systems represents far more than a temporary operational adjustment for construction sites; it is a fundamental paradigm shift in how the built environment generates, manages, and values energy. While project-specific nuances, regulatory gaps, and industry familiarity thresholds remain near-term hurdles, they are rapidly being outpaced by undeniable supply-side cost declines and powerful demand-side digital innovations. As battery costs reduce further and AI-driven optimisation platforms become standard practice, the barrier between physical infrastructure and intelligent energy management will entirely dissolve. By embracing early-stage collaboration and proactive policy adaptations today, developers, contractors, and policymakers can successfully position Singapore's built environment at the absolute forefront of a highly efficient, resilient, and fully decarbonised urban future.

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TABLES AND FIGURES

Figure 1: Use Cases for BESS across the Built Environment.

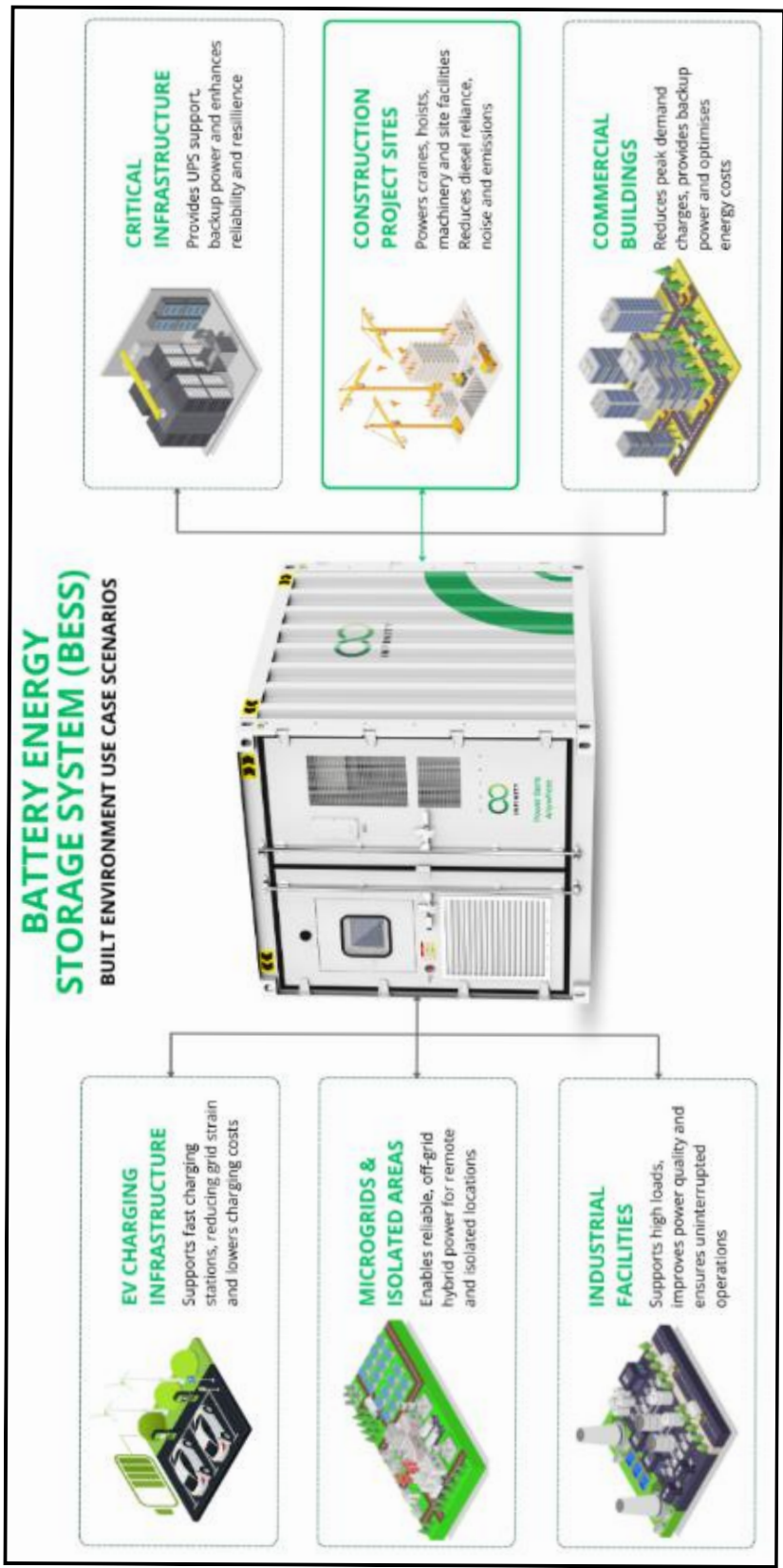


Figure 2: Core components of a typical BESS (Source: Infinity Cube).

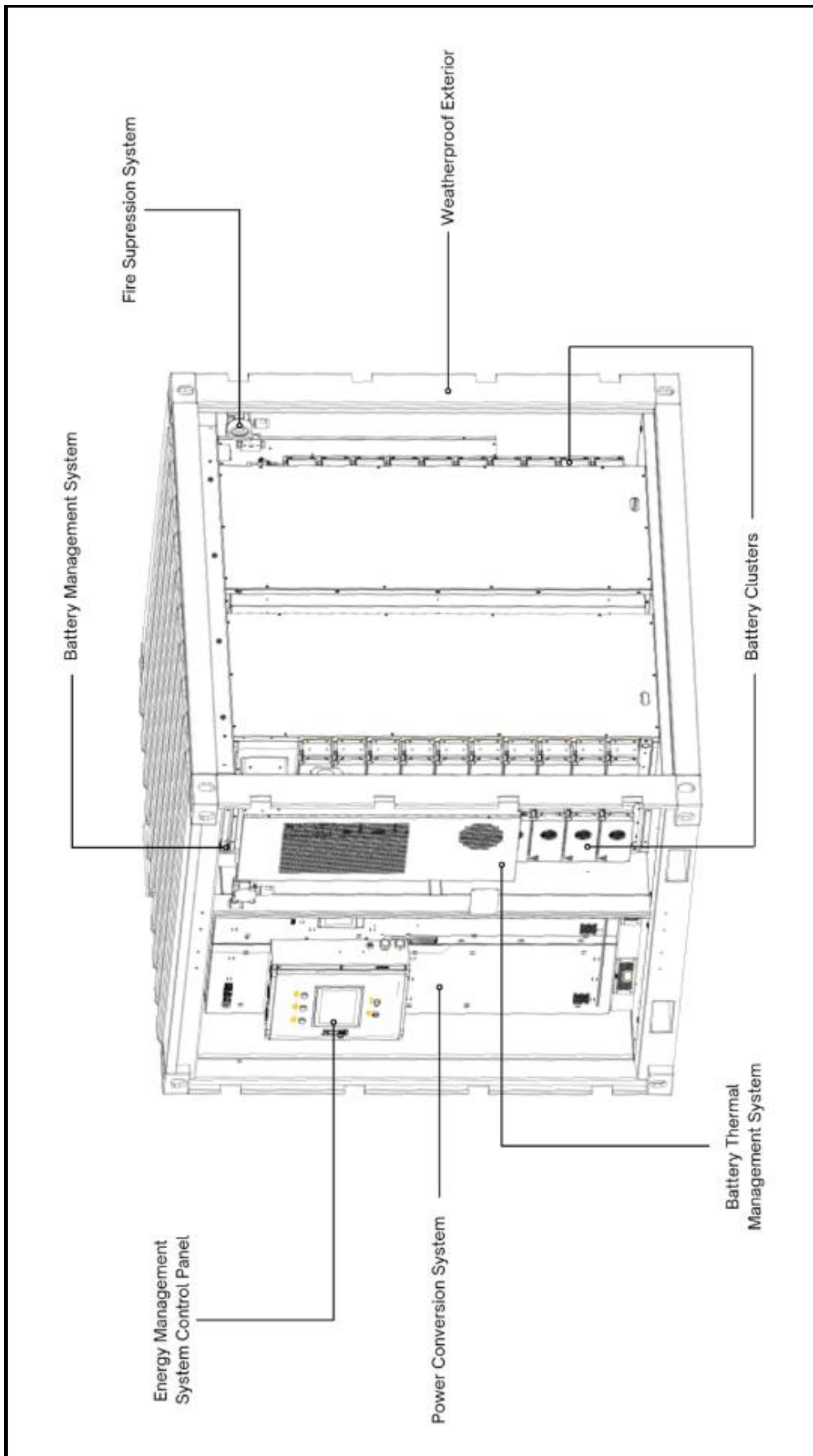


Table 1: Overview of common battery chemistries.
 Source: (Battlebury 1999; Suberu et al. 2014; Zhao 2023; ideona 2024; EV Lithium 2026b)

Battery Chemistry	Energy Density	Cycle Life*	Use Cases
Lead Acid Batteries	30 – 50 kWh/kg	300 - 1500	Residential/Utility scale: Automotive power and stationary backup power.
Vanadium Redox Flow Batteries (VRFB)	20 – 33 kWh/m3	20,000+	Industrial/Utility scale: Industrial scale storage, and microgrids for remote locations.
Lithium Iron Phosphate (LFP)	170 kWh/kg	2,000 – 6,000	All scales: Standard range EVs, residential, industrial, and utility scale energy storage
Lithium Nickel Manganese Cobalt (NMC)	350 kWh/kg	800 – 2,000	All scales: Long range EVs, portable electronics, residential, industrial, and utility scale energy storage
Lithium Manganese Iron Phosphate (LMFP)	230 kWh/kg	2,000 – 3,000	Residential/ Utility scale: Long range EVs and industrial energy storage

Figure 3: Characteristics of commercial BESS deployment models.

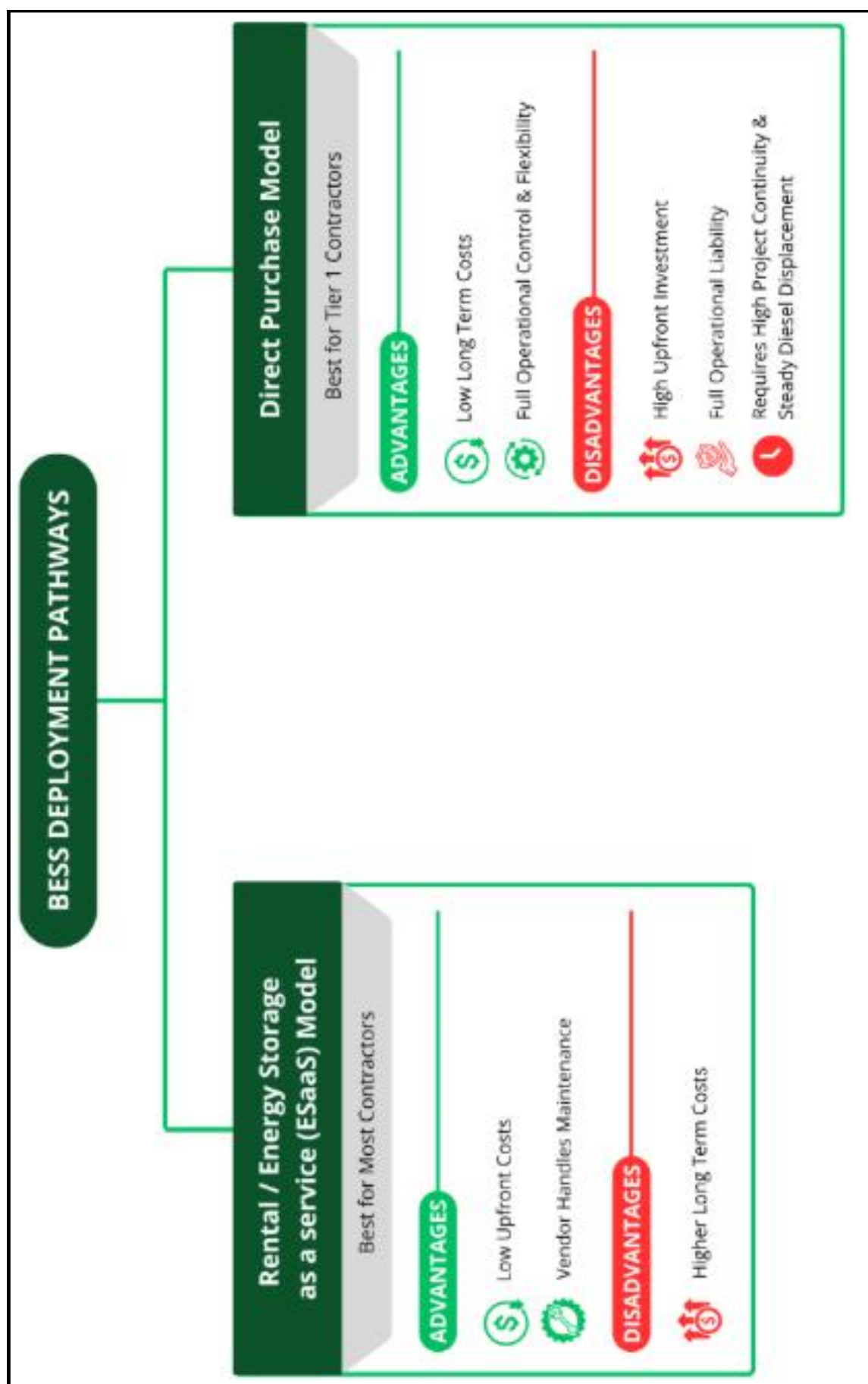


Figure 4: The regulatory pillars of mobile BESS deployment in Singapore.

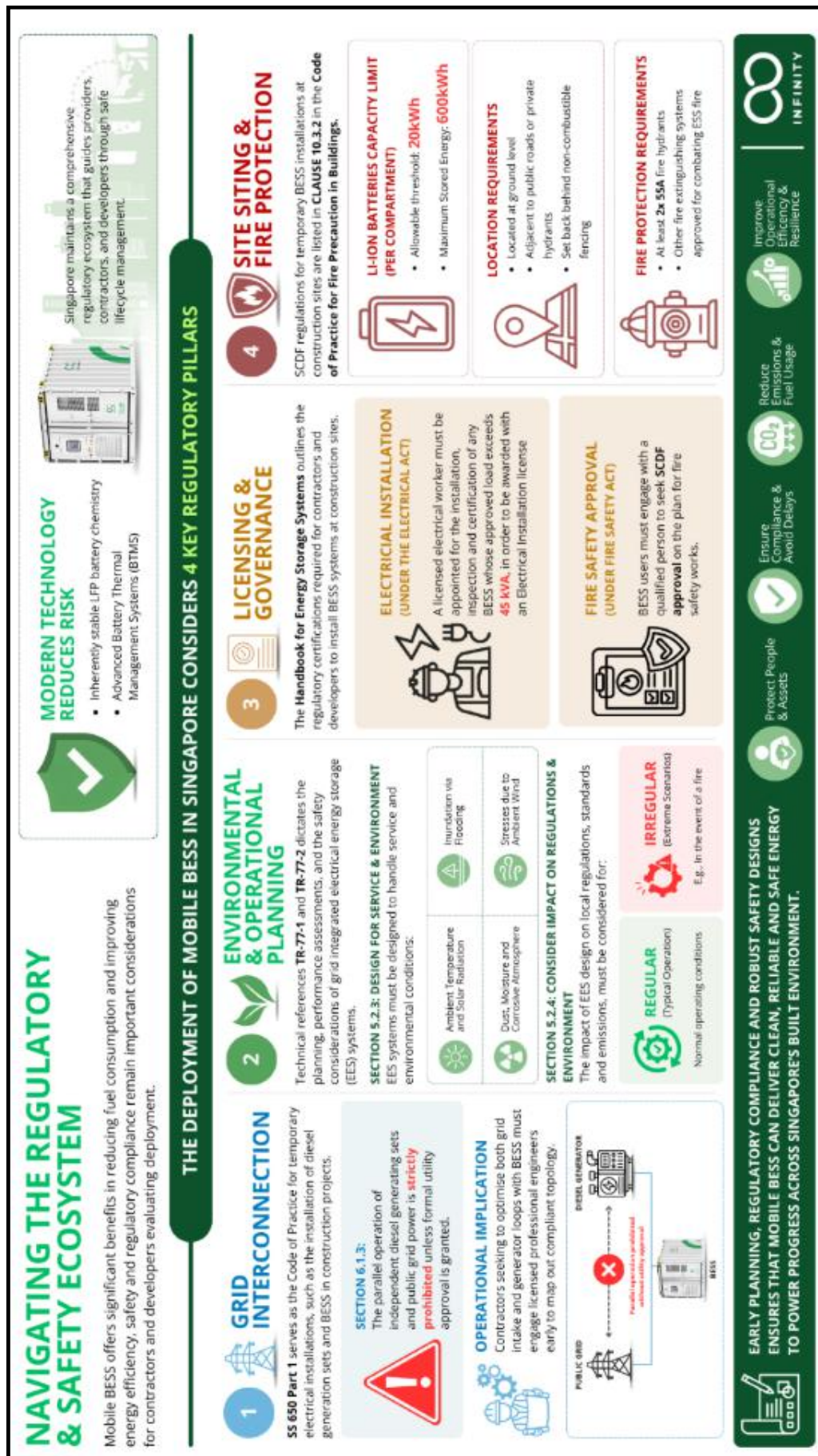


Table 2: BESS warning signs, indicators, and actions.

Warning Sign	Indicators	Action
Abnormal Odours	Sweet, acrid, or "chemical" smell emanating from the unit.	Immediately alert site supervisor; avoid prolonged exposure.
Unusual Sounds	Hissing, popping, or bubbling from within the enclosure.	Evacuate immediate area; contact BESS provider.
Visual Indicators	Swelling, bulging, or deformation of enclosure panels; visible smoke or vapour.	Initiate emergency protocol; call SCDF immediately.
BMS Alarms	Repeated or escalating BMS alerts (temperature, voltage, or current deviations).	Investigate immediately; do not reset without technical assessment.
Excessive Heat	Noticeable heat radiating from the unit beyond normal warmth	Shut down system if safe to do so; contact technical support

Table 3: Emergency Response Protocol for BESS Thermal Event

Step	Action
Evacuate	Clear all personnel from the immediate vicinity (minimum 30m exclusion zone).
Activate Alarm	Sound site emergency alarm; notify all workers.
Call SCDF	Dial 995 immediately. Do not attempt to fight the fire alone.
Do Not Use Water	Water can react with battery chemicals. Use Class D extinguishers (dry powder/sand) only if trained and safe to do so.
Isolate Power	If safe to do so, disconnect the BESS from all power sources (grid and generators).
Post-Event	Do not re-enter until SCDF declares safety. Maintain 24-hour monitoring watch—lithium-ion fires can reignite hours or days later.

Figure 5: Levelized cost of energy and grid emissions factors for Kimly Construction – Public Housing Project.

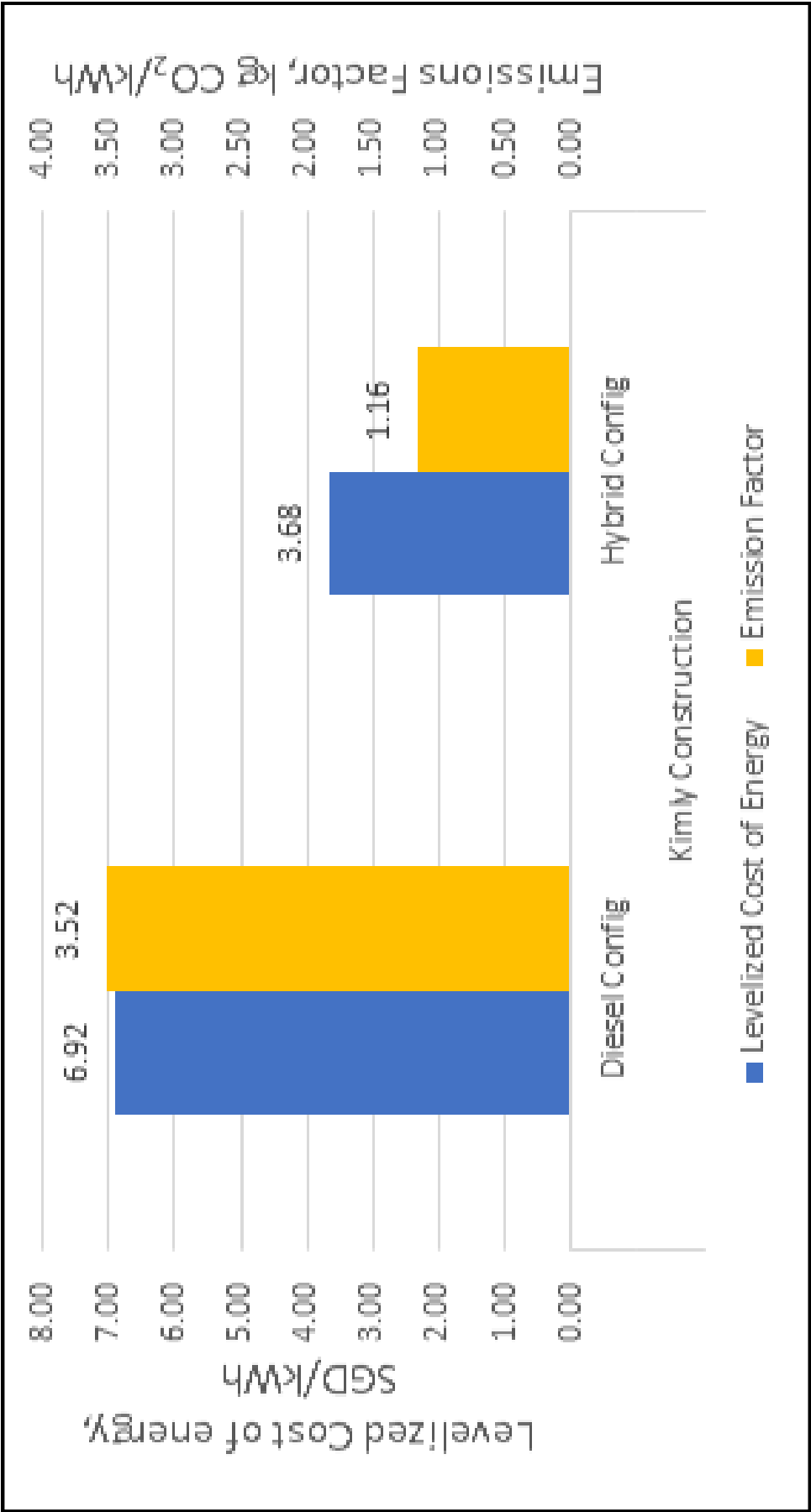


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Total energy demand (kWh)	10,100		95,400	
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Grid Cost (% Total)	-	-	-	42.80%
Carbon Footprint (kg CO2)				
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