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ELECTRIC VEHICLE BATTERY TYPE SUITABILITY IN V2L APPLICATIONS TO ENHANCE GRID LOAD FLEXIBILITY: A COMPARATIVE STUDY

Purpose of the research: *This study examines the potential of Vehicle-to-Load (V2L) technology as a practical tool for enhancing grid load flexibility through decentralized energy support. Special emphasis is placed on the influence of battery characteristics on V2L effectiveness.*

Methodology: *A comprehensive technical and comparative analysis is conducted, focusing on key battery-related parameters that affect V2L performance. These include usable capacity, inverter constraints, thermal regulation, and degradation behavior. The study evaluates three dominant battery chemistries—lithium iron phosphate (LFP), nickel manganese cobalt (NMC), and lithium titanate (LTO)—and three major cell formats (prismatic, pouch, cylindrical) to assess their suitability for real-world V2L use cases.*

Results: *LFP batteries demonstrate the best overall trade-off between safety, durability, and cost-efficiency under partial load conditions typical for V2L. Inverter limitations and thermal management are shown to significantly affect performance and longevity. Among cell formats, pouch cells are more vulnerable to thermal stress, while prismatic cells perform more consistently under moderate cycling regimes.*

Conclusions: *V2L technology offers a viable and increasingly accessible pathway to improve household-level energy autonomy and reduce strain on centralized grids during peak periods. The growing availability of commercial EVs equipped with LFP batteries strengthens the case for integrating V2L into smart grid strategies aimed at increasing load flexibility and resilience.*

Keywords: electric vehicles; Vehicle-to-Load (V2L); lithium-ion batteries; peak load shaving; battery performance; energy resilience

1. Introduction

The global shift towards energy system decentralization and accelerated transition to renewable energy sources have driven significant changes in electricity generation, distribution, and consumption, shaping new paradigms for sustainable development and energy security [1-2]. In Ukraine, these priorities are reflected in national strategies that emphasize the integration of renewables and distributed energy resources while ensuring system flexibility and reliability [2]. A substantial body of research has explored the trends and prospects of electric vehicle (EV) deployment, their integration into power systems, and the potential of EVs as flexible resources for load management and frequency regulation [3-8]. Studies have also examined the impact of EV charging on power quality and grid stability [9-13], as well as the role of microgrids and distributed generation in enhancing energy system resilience [6-7, 14]. While these contributions have expanded the understanding of EV-grid interactions and the broader potential of electrified transport for energy systems, the specific application of Vehicle-to-Load (V2L) technology remains underexplored, particularly in the context of its role in peak load management and grid load reduction.

Among emerging solutions, V2L technology has attracted significant attention as a practical and user-controlled option for decentralized energy support. V2L enables EVs to act as mobile power sources, supplying electricity directly to external devices, buildings, or homes without the need for grid interconnection [15]. Unlike Vehicle-to-Grid (V2G) solutions, which involve bidirectional energy flow between EVs and the grid infrastructure, V2L does not require regulatory approval or smart grid integration and is already implemented in a number of commercial EV models. This makes V2L particularly relevant for immediate deployment in countries with limited regulatory support for V2G, such as Ukraine.

V2L applications are especially promising for **peak load shaving, backup power supply,** and **integration with domestic renewable energy systems.** When used strategically, EVs can discharge stored energy to cover residential electricity needs during high-demand hours, reducing stress on the grid, lowering energy costs, and supporting energy resilience [16]. However, repeated V2L operation may lead to battery degradation, making the choice of battery chemistry and thermal management critical for long-term sustainability.

The purpose of this study is to compare different EV battery chemistries in the context of their suitability for V2L use, considering factors such as safety, cycle life, thermal stability, and power output. A particular emphasis is placed on the practical aspects of currently available EV models, technical constraints, and future development trends.

2. Material and Methods

Approaches and Use Cases of V2L Technology

V2L technology enables electric vehicles to function as decentralized power sources capable of delivering electricity to residential, commercial, or off-grid loads. This capability supports the broader goals of grid flexibility, energy cost reduction, and user-driven energy resilience. Several primary application scenarios have emerged for V2L technology:

One of the most prominent applications of V2L is peak load shaving, which involves reducing electricity drawn from the grid during times of highest demand. By powering essential loads such as lighting, refrigeration, and air conditioning during evening peaks, EVs equipped with V2L reduce the strain on grid infrastructure and help avoid the dispatch of costly peaker plants. This decentralized demand management approach can lower system-wide costs and carbon emissions while enhancing local energy reliability. Fig. 1 illustrates the use of V2L as backup source for essential load during peak demand hours [17].

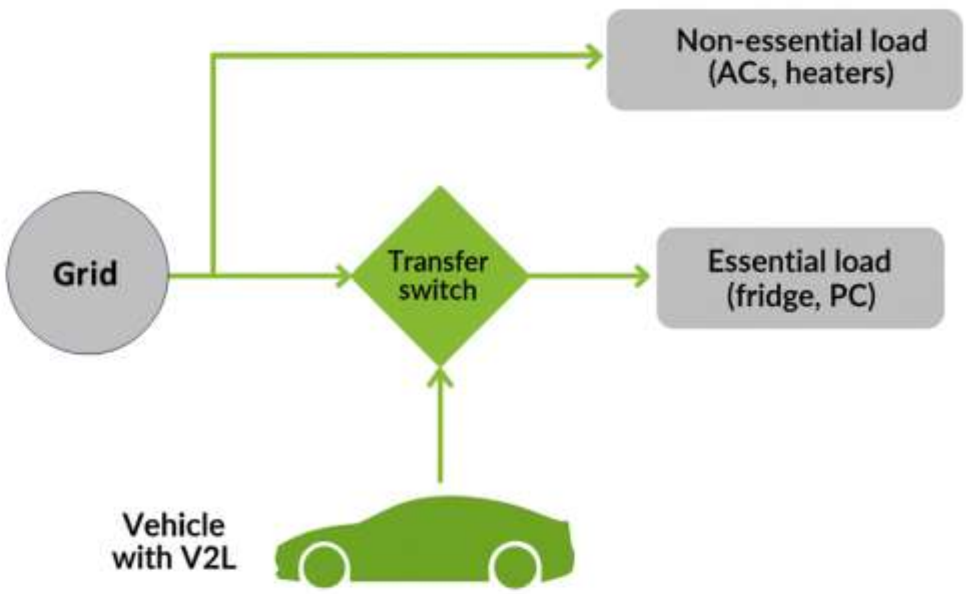

Figure 1 - *Vehicle-to-Load as backup source for essential load during peak hours*

The intermittent nature of solar and wind energy requires flexible storage and discharge solutions. EVs with V2L capability can store excess renewable energy generated during daylight hours and supply it in the evening when solar production drops [18-19]. This supports higher penetration of renewable energy in local energy systems and reduces dependency on fossil-based evening generation .

Real-World Deployments

Several successful pilot projects demonstrate the value of V2L and related bidirectional technologies in real-world conditions.

City of Boulder (USA): The Vehicle-to-Building (V2B) pilot used a Nissan LEAF to supply backup energy to a municipal recreation center during peak grid demand periods, showcasing V2L potential for public infrastructure [20].

PG&E (California): Bidirectional charging pilots explored Vehicle-to-Everything (V2X) use cases including V2H, V2B, and V2G. Financial incentives encouraged EV owners to participate in backup and grid-support programs, with promising results in both energy resilience and user satisfaction [21].

These projects reveal a growing role for V2L/V2X systems within broader grid modernization efforts.

Battery Considerations for V2L

The choice of battery chemistry directly influences the practicality and efficiency of V2L. Among available technologies, Lithium-Ion (Li-ion or LIB) and Lithium Iron Phosphate (LFP or $LiFePO_4$) batteries are the most commonly deployed in V2L-capable vehicles. Tab. 1 summarizes their key characteristics [22-24].

Table 1 - Comparative Analysis of Leading Battery Chemistries for V2L Applications

Feature	**Li-ion (NMC/NCA)**	**Lithium Iron Phosphate (LFP)**
Safety	Higher risk of thermal runaway; requires complex BTMS	Inherently stable chemistry; very low risk of thermal runaway.
Average Cycle Life	1,000 - 2,000 cycles (to 80% SoH)	3,000 - 7,000+ cycles (to 80% SoH)
Specific Energy	High (150-265 Wh/kg)	Moderate (90-160 Wh/kg)
Thermal Stability	Narrower operating range (e.g., 0°C to 45°C)	Wider operating range (e.g., -20°C to 60°C)
Nominal Cell Voltage	Higher (3.6-3.7V)	Lower (3.2V)
V2L Use Case Profile	Best for high-power, occasional V2L use where vehicle range is prioritized.	Ideal for high-frequency, long-duration V2L use where safety and longevity are paramount.

In addition, *Fig. 2* illustrates how LIBs outperform lead-acid batteries in every key dimension: system weight, energy density, operating temperature, and cycle life-confirming their suitability for V2L use.

Figure 2 - *Comparison of lithium-ion and lead-acid batteries on key operational parameters [25]*

Power Output and System Integration

The practical application of V2L also depends on the onboard inverter's power capacity. While high-end EVs like the Ford F-150 Lightning offer up to 9.6 kW of V2L output -enough to power an entire home -most mid-range vehicles deliver 2.2-3.6 kW [26-31]. Tab. 2 presents a comparative overview of selected commercially available EV models equipped with V2L functionality highlighting the two dominant battery chemistries used in EVs equipped with V2L: Nickel Manganese Cobalt (NMC) lithium-ion batteries and Lithium Iron Phosphate (LFP, or $LiFePO_4$). While NMC batteries generally provide higher energy density, LFP batteries offer greater thermal stability and longer cycle life, making them more suitable for frequent and prolonged V2L applications.

Table 2 - Technical Specifications of V2L-Capable EVs

№	Vehicle	V2L Power	AC Voltage	Battery Type
1	Hyundai Ioniq 5	3.6 kW	230-240 V	NMC
2	Kia EV6	3.6 kW	230-240 V	NMC
3	Kia EV9	3.6 kW	230-240 V	NMC
4	BYD Atto 3	2.2-3.0 kW	~220-240 V	LFP
5	BYD Seal	2.4 kW	~220-240 V	LFP
6	BYD Dolphin	~2.2 kW	~220-240 V	LFP
7	Ford F-150 Lightning	9.6 kW	240 V	NMC/NCA
8	MG ZS EV	2.2 kW	230-240 V	NMC
9	MG 4 (2023)	2.2 kW	230-240 V	LFP
10	Nissan Leaf	3.6 kW	230-240 V	NMC

As shown, most V2L-capable vehicles currently offer power outputs in the range of 2.2 to 3.6 kW, which is sufficient to supply essential household loads or support temporary off-grid operation. An exception is the Ford F-150 Lightning, which delivers up to 9.6 kW, enabling full-home backup for several days under certain conditions. Given the increasing diversity of EV models and battery architectures, the effectiveness of V2L depends not only on chemistry, but also on battery capacity, power electronics, discharge efficiency, and thermal control. These factors are explored in the following section.

Battery Chemistries and Cell Architectures: Implications for V2L Use

The effectiveness and safety of V2L operation depend not only on the power electronics and inverter design but also fundamentally on the characteristics of the battery itself. Different battery chemistries and cell formats used in EVs exhibit significant variation in terms of energy density, thermal performance, longevity, and mechanical integrity. These properties, in turn, determine how well a given battery system performs under the operational conditions specific to V2L use, like frequent discharges, moderate loads, thermal cycling, and stationary energy supply.

Among currently deployed technologies, Li-ion batteries remain the dominant choice in most EV platforms. This popularity stems from their favorable balance between energy density, efficiency, relatively low self-discharge rate, and scalability. Li-ion batteries can store a significant amount of energy per unit weight and volume, making them ideal for mobility. These same characteristics are beneficial for V2L applications, especially when the battery is expected to deliver several kilowatt-hours of power to external devices or households. Moreover, the ability of Li-ion batteries to withstand hundreds to thousands of charge-discharge cycles ensures reliability in repeated V2L use.

Within the broad category of Li-ion batteries, LFP has gained increasing attention, especially in Chinese-manufactured EVs [32]. Although its energy density is lower than that of Nickel-based variants (such as NMC and NCA), LFP offers unparalleled safety, high thermal tolerance, and long operational life. These qualities make it well-suited for V2L scenarios where batteries may be discharging for extended periods and subjected to variable temperatures. The stable crystal structure of LFP minimizes the risk of thermal runaway as critical safety consideration in backup power or off-grid energy contexts. That means the EV equipped with a LFP battery is likely to deliver more stable and consistent V2L performance over time, with lower degradation rates compared to its NMC/NCA counterparts.

By contrast, Nickel-Metal Hydride (NiMH) batteries (once widely used in early hybrid electric vehicles) are now largely obsolete in fully electric platforms [33-34]. Although NiMH batteries are known for their robustness and tolerance to abuse, they exhibit significantly lower energy density and higher self-discharge than Li-ion batteries. As a result, their applicability to V2L is limited: while they can technically support small-scale discharges, their weight, volume, and limited usable capacity make them impractical for extended or high-power applications.

Looking forward, Solid-State Batteries and Lithium-Sulfur (Li-S) chemistries represent promising innovations in the EV landscape [35]. Solid-state batteries, which replace liquid electrolytes with solid materials, offer the potential for dramatically improved energy density, safety, and fast-charging capabilities. If successfully commercialized, they could transform the capabilities of V2L systems by providing compact, high-capacity storage with reduced fire risk. Similarly, lithium-sulfur batteries, by employing abundant and inexpensive sulfur as the cathode, promise both cost reduction and high specific energy. However, both technologies remain in development stages, and their real-world performance, especially under repetitive V2L cycling, has yet to be validated.

In addition to chemistry, the physical structure or "cell format" of the battery-namely cylindrical, prismatic, and pouch cells-plays an important role in how effectively the battery can support V2L. These formats, as presented in Fig. 3, differ not only in packaging and energy density but also in heat dissipation, structural stability, and integration into vehicle platforms [36-37]. Each format presents trade-offs in terms of energy density, thermal characteristics, packaging, and mechanical robustness.

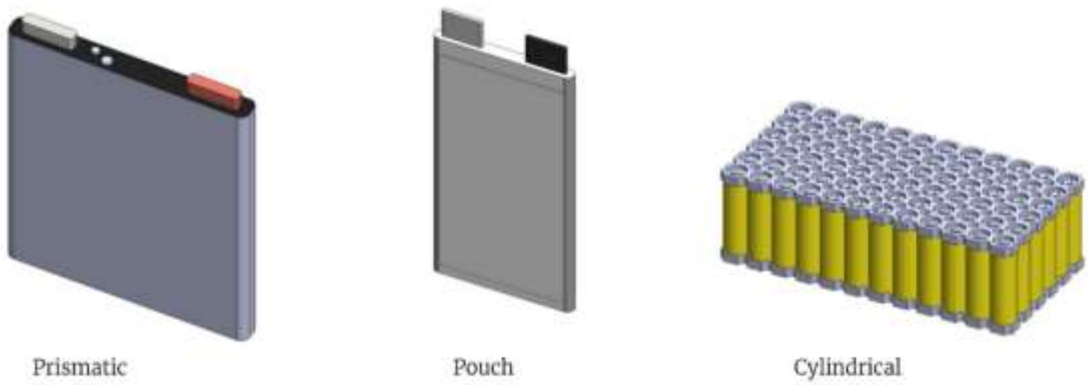

Figure 3 - *Common EV battery cell formats: prismatic, pouch, and cylindrical*

*Cylindrical cells***,** known for their standardized design and long manufacturing history, offer excellent mechanical strength and are relatively easy to cool. Their rigid metal casing protects against deformation and improves thermal conductivity, which can be beneficial during prolonged discharges as in V2L operation. However, the use of individual cylindrical units introduces gaps in packaging, slightly lowering volumetric energy density and increasing the overall weight of the battery pack.

Prismatic cells, commonly found in EVs from manufacturers such as BMW and Volkswagen, offer efficient use of space and higher capacity per unit volume. Their flat and compact structure allows for more flexible pack design. However, their rectangular casing can make them more vulnerable to swelling or uneven thermal expansion, requiring precise thermal management systems-particularly during high-current V2L discharges.

*Pouch cells***,** characterized by their lightweight and flexible laminate packaging, provide the highest packing efficiency and design versatility. This format enables automakers to tailor battery modules to constrained vehicle architectures. Nevertheless, pouch cells are mechanically delicate and prone to swelling under stress, which can compromise performance and safety in applications like V2L that involve sustained energy delivery. Without proper structural support and cooling, pouch cells are more susceptible to degradation or failure over time.

Taken together, these considerations suggest that the most suitable battery configuration for V2L functionality combines a thermally stable chemistry, such as LFP, with a robust and well-managed cell format**,** like prismatic or cylindrical cells. As V2L adoption expands, vehicle designers and battery engineers must jointly optimize chemistry and packaging to meet both driving and energy export needs, ensuring performance, safety, and longevity.

To summarize the strengths and limitations of different batteries for V2L, Tab. 3 summarizes six representative combinations of battery chemistries and cell formats. The comparison is based on five technical criteria relevant to V2L performance: energy density, cycle life, thermal stability, mechanical strength, and overall suitability for V2L operation. This classification highlights how the integration of chemical and structural properties defines a battery system’s capability to safely and efficiently deliver power to external loads over repeated cycles.

Table 3 **-** Comparative assessment of battery chemistries and cell formats for V2L applications

Battery Type & Cell Format	**Energy Density**	**Cycle Life**	**Thermal Stability**	**Mechanical Strength**	**V2L Suitability**
LFP - Prismatic	Medium	High	High	Moderate	Excellent
LFP - Pouch	Medium	High	High	Low	Good
NMC - Cylindrical	High	Medium	Medium	High	Good
NMC - Pouch	High	Medium	Medium	Low	Moderate
LTO - Cylindrical	Low	Very High	Very High	High	Niche
NiMH - Prismatic	Low	Medium	High	Moderate	Limited

This comparative matrix highlights how the interplay between battery chemistry and cell architecture directly impacts the technical suitability of EV batteries for V2L use. In particular, chemistries with high thermal stability and long cycle life, such as LFP; and mechanically stable format, such as prismatic or cylindrical cells-offer the most reliable performance under repeated discharge cycles. As V2L deployment scales, optimal combinations of these factors will be key to ensuring safe, efficient, and long-lasting energy delivery from electric vehicles to external loads.

Battery Criteria for Effective V2L Performance

While battery chemistry and cell format are key structural determinants of a vehicle's energy storage capabilities, the actual effectiveness of V2L functionality is shaped by a broader set of technical parameters. These include usable energy capacity, inverter performance, thermal control, degradation behavior, and overall system efficiency. In real-world applications, where loads fluctuate, ambient temperatures vary, and energy must be delivered continuously – these factors collectively determine the reliability, safety, and duration of V2L power supply.

Usable Capacity and State-of-Charge Buffers

Electric vehicle batteries are typically rated by their total nominal capacity, expressed in kilowatt-hours (kWh). However, the actual portion of this capacity available for use in V2L scenarios-referred to as usable capacity-is often significantly lower. Manufacturers routinely implement state-of-charge (SoC) buffers at the upper and lower ends of the charge range to reduce battery wear and prevent thermal or chemical instability. For example, a vehicle displaying 100% SoC may be utilizing only 90-95% of the battery's true charge range. Conversely, discharging to 0% rarely means that the battery is fully depleted.

This practice enhances battery longevity but introduces practical constraints for V2L users. The usable energy available for external loads may be noticeably less than anticipated, particularly in systems with conservative battery management strategies [38]. Users planning V2L for critical backup or extended off-grid use must account for these buffers in estimating how long their EV can power external devices.

Power Output Limitations

Another decisive factor in V2L performance is the maximum continuous power output, which determines which devices or systems can be powered and for how long [39]. This output is not solely a function of battery size, but is also influenced by the onboard inverter's capacity (responsible for DC-to-AC conversion), thermal constraints that limit sustained current, and the battery's internal electrical properties, such as resistance and discharge rate.

Higher-end EVs like the Ford F-150 Lightning are designed to serve as mobile backup generators, offering up to 9.6 kW of V2L output, sufficient to power an entire household during outages. In contrast, mid-market vehicles such as the Hyundai Ioniq 5 or Kia EV6 provide around 3.6 kW, which is adequate for running essential household loads like refrigerators, lighting, laptops, and small appliances. These values define the practical scope of V2L: from basic emergency backup to partial home support or remote worksite operation.It is important to note that peak power may differ from sustained power, and actual performance can degrade under prolonged load or high ambient temperature, especially without adequate cooling.

Round-Trip Efficiency

Efficiency is a critical but often overlooked aspect of V2L operation. The process of supplying AC power to external devices involves multiple energy conversion steps, primarily drawing DC power from the battery, converting it to AC via the onboard inverter and delivering it through external connectors and wiring. While modern inverters can achieve theoretical efficiencies of up to 95%, real-world conditions introduce losses. Factors such as partial load operation, heat buildup, poor power factor, and low inverter quality can reduce round-trip efficiency to 79-88%, or even lower in unfavorable scenarios [21].

These efficiency losses must be factored into both design expectations and user behavior. For instance, a user expecting to draw 10 kWh from a vehicle may receive only 8-8.5 kWh at the output. This discrepancy can affect backup duration calculations and should be made transparent in product documentation.

Thermal Management and Operational Stability

Thermal stability is particularly critical for sustained V2L discharges. Delivering several kilowatts of power over an extended period generates heat in the battery cells, inverter circuits, and cabling infrastructure. Without active cooling, this heat can accumulate, leading to performance throttling or even automatic shutdown to prevent damage [38-39]. Vehicles equipped with advanced thermal management systems-such as liquid cooling loops and thermal throttling logic-can maintain stable output for longer durations. In this context, LFP batteries demonstrate significant advantages due to their broader thermal operating range and lower sensitivity to overheating, allowing more stable energy delivery in hot climates or during summer outages.

However, thermal behavior is also linked to cell format. Cylindrical cells typically dissipate heat more effectively than pouch cells, while prismatic cells require more uniform cooling systems to avoid hot spots. Therefore, the combination of chemistry, format, and thermal architecture must be holistically considered in evaluating V2L stability.

Battery Degradation Under V2L Load

Like all electrochemical systems, EV batteries degrade over time. V2L operation contributes to this degradation, primarily by increasing the number of partial or full cycles, extending discharge durations, and potentially deepening depth-of-discharge (DoD) profiles [40-41]. While occasional V2L use-such as for emergency backup-has minimal impact, frequent or daily V2L discharging can accelerate capacity fade and resistance growth, especially in systems with aggressive power profiles or poor cooling.

Mitigation strategies include maintaining depth of discharge within a moderate range (e.g., 20-60%) operating within a mid-range SoC window (40-80%), avoiding full charge or deep depletion and limiting discharge current to moderate levels (typically between C/10 and C/5), depending on battery specification as well. Following such practices helps to preserve battery health over the long term, ensuring that V2L remains a sustainable functionality rather than a source of premature degradation. For users integrating V2L into their daily routines-such as those using EVs to support solar self-consumption or off-grid work-these considerations are particularly critical.

The suitability of an electric vehicle for V2L applications is not solely determined by its nominal battery type or capacity. Several technical parameters influence the actual performance and reliability of V2L operation in real-world conditions.

Comparative Suitability of Lithium-Based Chemistries for V2L

Beyond thermal management and power delivery, the long-term viability of V2L applications also depends on the underlying battery chemistry. Fig. 4 presents a radar chart comparison of six major lithium-based chemistries used in EVs, assessed across six key technical criteria: energy density, specific power, safety, performance, lifespan, and cost [42].

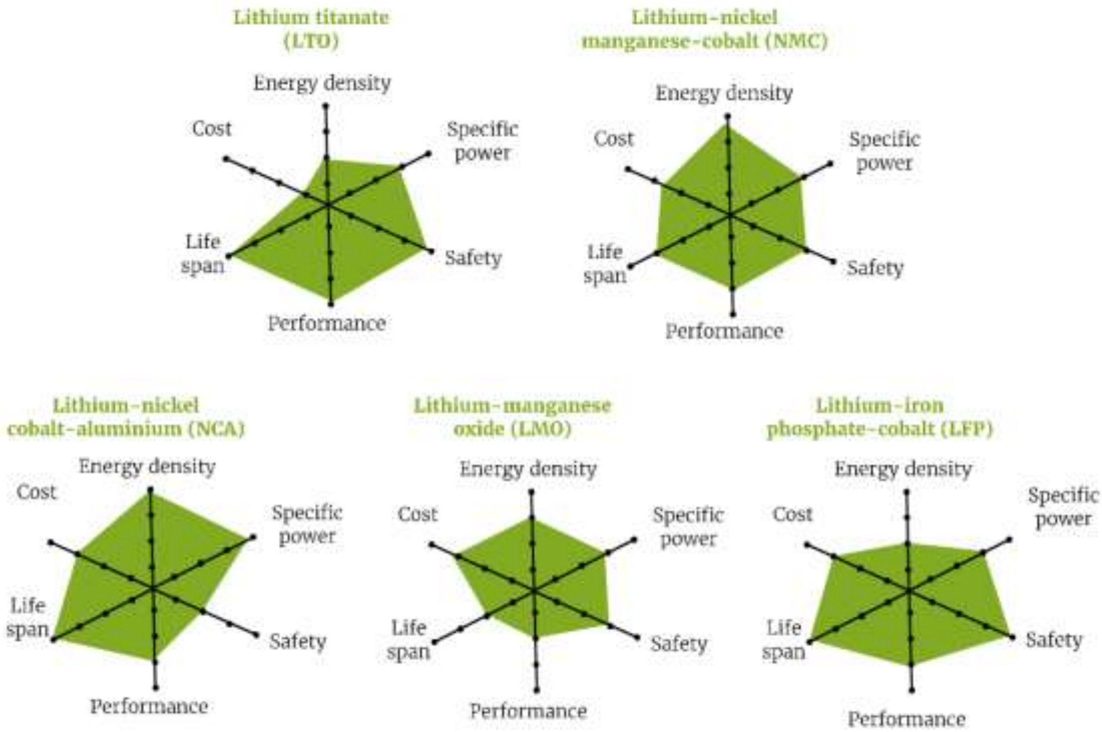

Figure 4 - *Radar comparison of major lithium-based battery chemistries for EV applications based on key performance criteria*

From a V2L perspective, the most relevant characteristics are safety, thermal stability, cycle life, and cost-efficiency under partial loads. The following observations emerge from the comparison above. Among the lithium-based battery chemistries evaluated, LFP emerges as the most balanced and well-suited option for V2L applications. This chemistry is distinguished by its high safety profile, stemming from intrinsic thermal stability and the use of a non-flammable electrolyte. LFP batteries also offer remarkable cycle life, often exceeding 3,000 to 5,000 cycles under moderate depth-of-discharge conditions, which makes them highly favorable for long-term and recurring V2L usage. While their energy density is comparatively moderate, this limitation is generally less critical in stationary or home-support V2L contexts, where safety, longevity, and consistency are more important than compactness.

In contrast, NMC and NCA chemistries provide higher energy density and specific power, which benefits dynamic driving performance. However, these advantages are offset by shorter cycle life and greater thermal sensitivity. Under repeated V2L usage-especially in warm climates or during sustained discharges-these batteries are more prone to accelerated degradation, which may compromise their long-term reliability in grid-supporting roles. LTO represents a unique case, offering exceptional resistance to wear and outstanding charging stability. Its ability to withstand extremely high cycle counts without significant capacity loss makes it theoretically ideal for intensive V2L use. Nonetheless, LTO's low energy density and high production cost have so far limited its deployment in mainstream passenger EVs, particularly those targeting V2L functionality.

Other chemistries, such as LMO and LCO, are rarely implemented in V2L-equipped EVs. Their application is constrained by safety concerns, thermal limitations, or rapid aging characteristics, making them less viable for systems that require repeated and stable auxiliary power delivery. In conclusion, LFP batteries currently offer the most favorable profile for V2L applications, especially for households or microgrid-level systems that rely on reliable, repeatable discharge cycles. The increasing availability of LFP-based models (e.g., BYD Seal, Dolphin, Atto 3) further supports their growing role in the decentralized energy landscape.

3. Results and Discussions

The long-term effectiveness of V2L systems is inextricably linked to the fundamental characteristics of the battery technologies upon which they rely. While thermal management and inverter architecture define short-term performance, the sustainability, safety, and economic feasibility of V2L over the battery's life cycle are determined primarily by its electrochemical composition. Among commercially available options, LFP batteries present the most favorable combination of properties for V2L operation. Their intrinsic thermal stability, coupled with a non-flammable electrolyte, ensures high safety margins under extended discharge conditions. Furthermore, LFP batteries demonstrate exceptional resistance to degradation, often supporting several thousand cycles with minimal capacity loss-particularly when operated within moderate DOD ranges. This resilience makes them especially suitable for applications where the battery is expected to discharge regularly, such as daily home backup or integration with rooftop solar systems. While their energy density is lower than that of other lithium-based chemistries, this trade-off is less relevant in V2L contexts, where weight and volume constraints are secondary to reliability and longevity.

Batteries based on NMC and NCA chemistries deliver higher specific energy and power output, which benefits vehicle propulsion but introduces compromises for stationary or repeated auxiliary discharging. These chemistries are more sensitive to elevated temperatures and repeated cycling, and their thermal stability is comparatively lower. In real-world V2L usage-particularly in warmer climates or during long-duration discharges-this may lead to accelerated aging and reduced effective lifespan. Nevertheless, the widespread deployment of NMC/NCA chemistries in modern EVs means that many V2L-enabled vehicles rely on these systems, necessitating careful management of their operational parameters.

More specialized chemistries, such as LTO, offer exceptional cycle life and ultra-fast charging characteristics. However, their significantly lower energy density and high production cost have limited their adoption in mainstream passenger EVs. From a V2L perspective, LTO batteries hold promise for niche use cases that require frequent, shallow discharges with minimal degradation-but they are unlikely to play a central role in large-scale deployment. Meanwhile, chemistries such as lithium manganese oxide (LMO) and lithium cobalt oxide (LCO) are generally considered suboptimal for V2L. Their limited thermal margins, susceptibility to aging, and declining presence in modern EV platforms reduce their relevance in current and future system designs.

Together, these observations indicate a clear trend. LFP batteries are emerging as the optimal platform for V2L functionality, especially in household and microgrid-scale use cases. Their growing presence in EV models such as the BYD Seal, Dolphin, and Atto 3 reinforces this direction, demonstrating how battery chemistry decisions are beginning to align not only with vehicle performance but also with broader energy resilience strategies. As regulatory frameworks and energy infrastructure continue to evolve [43-46], the compatibility of EV batteries with distributed energy use-including V2L-may become a critical differentiator in technology and market adoption.

4. Conclusions

This study examined the technical viability and comparative performance of various EV battery chemistries in the context of V2L applications aimed at reducing grid load and enhancing decentralized energy resilience. The analysis confirms that battery characteristics such as thermal stability, cycle life, discharge behavior, and energy conversion efficiency play a critical role in the sustainability and safety of V2L operation. While all lithium-based chemistries present distinct strengths and limitations, not all are equally suitable for repeated auxiliary discharging under real-world conditions.

Among currently available options, LFP batteries offer the most favorable profile for frequent and extended V2L use. Their high thermal tolerance, non-flammable composition, and extended cycle life ensure stable performance and minimal degradation under moderate discharge depths. These properties are particularly advantageous for residential users seeking reliable backup power or to offset peak-hour consumption. Although LFP batteries provide slightly lower energy density compared to NMC or NCA variants, this trade-off is negligible in stationary or semi-stationary V2L applications where safety and longevity are paramount.

It is found that battery format (cell architecture) significantly influences heat dissipation and mechanical integrity, further affecting V2L performance. Prismatic and cylindrical formats show better structural resilience and thermal control compared to pouch cells, making them more appropriate for applications involving sustained energy delivery. In tandem with chemistry, these factors must be jointly considered in the selection and deployment of V2L-capable EVs, particularly as the number of commercial models supporting V2L functionality continues to grow.

By enabling EVs to temporarily power homes or critical loads, V2L technology contributes to peak shaving, enhances household energy autonomy, and supports grid flexibility-especially in regions where regulatory or technical barriers hinder full V2G integration. As battery technologies continue to evolve, and as energy systems decentralize further, V2L is poised to play an increasingly important role in the distributed energy ecosystem.

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ПОРІВНЯЛЬНА ОЦІНКА ТИПІВ БАТАРЕЙ ЕЛЕКТРОМОБІЛІВ ДЛЯ ЗАСТОСУВАННЯ В ТЕХНОЛОГІЇ V2L З МЕТОЮ ПІДВИЩЕННЯ ГНУЧКОСТІ НАВАНТАЖЕННЯ ЕЛЕКТРОМЕРЕЖІ

Мета дослідження: *Проаналізувати придатність технології Vehicle-to-Load (V2L) як інструменту підвищення гнучкості навантаження електромережі за рахунок децентралізованої підтримки енергопостачання, з урахуванням акумуляторних характеристик.*

Методика реалізації: *Проведено порівняльний аналіз технічних параметрів, що впливають на ефективність V2L: корисна ємність, обмеження інвертора, тепловий режим та чутливість до деградації. Оцінено три хімічні типи батарей (LFP, NMC, LTO) і три формати комірок (призматичні, пакетні, циліндричні) для реальних сценаріїв застосування.*

Результати дослідження: *Батареї типу LFP виявили найкращий баланс між безпекою, довговічністю та економічною доцільністю для режимів часткового навантаження. Формат пакетних комірок виявився більш вразливим до теплових коливань, у той час як призматичні проявили стабільнішу роботу.*

Висновки: *V2L є перспективним рішенням для підвищення енергетичної автономії домогосподарств і зниження навантаження на мережу в пікові години. Поширення EV з LFP-батареями створює умови для ефективної інтеграції V2L у стратегії «розумних» мереж.*

Ключові слова*: електромобілі; Vehicle-to-Load (V2L); літій-іонні батареї; зменшення пікового навантаження; ефективність батарей; енергетична стійкість.*

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