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Solar photovoltaic systems adoption for passive houses in New Zealand: A mixed-methods analysis of trends and influencing factors

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ABSTRACT

Solar photovoltaic systems (SPVS) can complement Passive Houses (PHs) by reducing grid dependence, emissions, and household energy costs. However, existing SPVS–PH research has emphasised technical performance and modelling, with limited attention to stakeholder, financial, policy, and market factors shaping adoption. This gap is evident in New Zealand, where SPVS uptake is increasing in conventional housing but remains limited in PHs. This study investigates the trends, drivers, barriers, and strategies influencing SPVS adoption in New Zealand PHs.

A sequential mixed-methods approach was used, comprising document analysis, 34 interviews, and a survey of 96 building and energy professionals. Qualitative data were analysed thematically, while survey responses were examined using mean ranking (M), one-sample *t*-tests, and reliability testing in Statistical Package for the Social Sciences (SPSS). Findings show that New Zealand's SPVS capacity reached 573 MW in 2024, while PH Plus and Premium certifications remain limited but are gradually increasing. Interviews identified 13 drivers, 18 barriers, and 18 strategies. Survey results ranked the strongest drivers as low-carbon transition support (M = 4.57), and declining SPVS costs (M = 4.55). The strongest barriers were budget constraints (M = 4.09) and low solar buy-back rates (M = 3.87); the strongest strategies were optimised design and installation (M = 4.54) and battery integration (M = 4.53).

Although limited to stakeholder perceptions in New Zealand, the study shows adoption is shaped by financial viability, policy support, and early-stage design integration, thereby contributing to Sustainable Development Goals 7 (Affordable & Clean Energy) and 13 (Climate Action).

1. Introduction

The building sector is recognised as a significant contributor to global greenhouse gas emissions [1]. Given this, total CO_2 emissions from buildings account for approximately 38% and 35% of global energy consumption (UNEP, 2022) and may increase significantly by 2035 [2,3]. Addressing this challenge directly contributes to Sustainable Development Goal 13 (Climate Action), which calls for urgent action to combat climate change and its impacts [4]. As New Zealand advances toward its 2050 net-zero target, decarbonising the residential sector is essential and will require improved building efficiency and the integration of renewable energy systems [5]. Passive Houses (PHs), recognised for their stringent energy-efficiency standards, are a key model for low-energy building transitions [6]. PHs utilise high-performance insulation, airtight construction, and mechanical heat-recovery ventilation to achieve up to a 90% reduction in space-heating demand relative to standard buildings [7]. However, pHs remain dependent on grid electricity for lighting, appliances, and auxiliary systems, highlighting the need for complementary on-site generation to achieve complete decarbonisation.

Solar photovoltaic systems (SPVS) offer a compelling solution, providing households with resilience against unpredictable energy prices, reduced exposure to grid outages (Ruokamo et al., 2023), and alignment with national carbon mitigation targets [5,8]. SPVS capacity in New Zealand has increased to 573 MW by December [9], accounting for 1.4% of total electricity generation [10]. However, its potential contribution to low-energy buildings, such as PHs, remains under-investigated, partly because ongoing technical and market challenges

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continue to constrain wider SPVS deployment. These challenges include seasonal generation–demand imbalances and low buy-back rates, which remain barriers to the broader diffusion of SPVS in New Zealand (Griffith et al. [9,11]). Globally, countries like Germany have mandated rooftop PV on new residential buildings, supported by financial incentives, resulting in SPVS adoption rates exceeding 40% [12]. In contrast, New Zealand's policy environment for SPVS, however, remains largely voluntary, with no equivalent requirements for integrating SPVS into new buildings. Furthermore, although PH Plus and PH Premium standards encourage renewable generation, only a few certified projects currently exist in New Zealand [13,14].

Accordingly, this study is informed by the Technology Acceptance Model (TAM) and socio-technical transitions theory. TAM provides a behavioural lens for understanding how stakeholders' perceptions of usefulness, ease of implementation, and acceptance influence technology adoption [15]. In contrast, socio-technical transitions theory explains how adoption is shaped by wider interactions among technologies, users, markets, regulations, infrastructures, professional practices, and institutional arrangements [16].

This study contributes to the existing research by integrating TAM with a socio-technical transitions perspective to examine SPVS-PH adoption in New Zealand. While previous studies have largely focused on technical performance, energy modelling, and life-cycle impacts [11,17,18], limited research has examined how stakeholder perceptions and wider financial, policy, market, and professional conditions shape SPVS adoption in PHs. Accordingly, the aim is to examine stakeholders' perceptions of SPVS-PH adoption in New Zealand through the following research questions: 1) What is the current adoption trend for SPVS in PHs across New Zealand? 2) What are the drivers and barriers to adopting SPVS for PHs in New Zealand? 3) What strategies can improve SPVS–PH adoption in New Zealand? 4) What are the most critical factors influencing SPVS adoption for PHs in New Zealand? To address these questions, the study combined document analysis, semi-structured interviews, and a survey. The remaining sections of this paper are structured as follows: Section 2 provides an overview of the existing research. Section 3 provides the methodology description. Sections 4 and 5 present the results and discussion. Finally, Section 6 presents the conclusions and outlines potential directions for future research.

2. Literature review

2.1. SPVS-PH adoption landscape and influencing factors

Understanding the factors influencing the adoption of SPVS in PHs has become an increasingly important research focus in sustainable building practice. Existing studies generally agree that SPVS–PH integration can reduce operational energy demand, emissions, and household reliance on grid electricity. However, the evidence base is methodologically uneven; most studies on integrating SPVS into PHs have prioritised technical simulations, lifecycle assessment, and energy modelling. For example, a recent review found that nearly 80% of SPVS–PH studies adopted modelling-based approaches, highlighting emission reductions and operational efficiency but often neglecting social and institutional dynamics [19]. One such simulation-based study showed that SPVS–PH configurations could cut household emissions by up to 98% compared to standard builds [20]. While these studies demonstrate technical potential, they often assume favourable design and operating conditions and provide limited insight into real-world adoption decisions.

However, real-world uptake varies considerably across contexts. For example, Germany's strong uptake (over 40%) is underpinned by regulatory mandates (e.g., the 2023 rooftop PV law) and financial instruments such as feed-in tariffs and concessional loans [12,21]. On the contrary, Norway has pursued uptake through public demonstration projects such as PH-Premium, fostering wider acceptance [22]. In New Zealand, however, adoption is nascent and/or largely undocumented [13,14], with few studies addressing the actual integration of SPVS into PHs, which receive comparatively limited attention. This contrast suggests that adoption may be determined not only by technical feasibility but also by policy design, market incentives, and stakeholder confidence.

Globally, 18 drivers and nine barriers to SPVS–PH adoption have been documented, highlighting an interplay of technical, behavioural, and institutional factors [19]. However, much of this evidence is derived from technically oriented studies, leaving the relative importance of these factors in specific national contexts unclear. Among these, the visibility of successful SPVS-PH projects has been found to enhance stakeholder confidence and accelerate adoption [12]. Moreover, financial incentives such as subsidies, low-interest loans, and tax credits have significantly accelerated SPVS adoption in Europe[22]. From a performance standpoint, the SPVS-PH system yields substantial energy savings and shows a considerable reduction in energy consumption[23].

The literature can therefore be systematically understood through technical, economic, and behavioural dimensions. Technically, SPVS–PH integration is supported by PHs' low energy demand, which can allow smaller PV systems to meet a larger share of household demand. However, technical feasibility does not remove practical constraints such as roof orientation, solar access, system sizing, battery storage, and grid connection conditions. In New Zealand, research on SPVS within the broader context of low-energy buildings highlights significant challenges that may also apply to the PH context. The studies identify a technical and economic barrier: the seasonal mismatch between summer SPVS surpluses and winter heating demand[11,24]. Within this dynamic, households often export surplus electricity at low tariffs (8–17 c/kWh) only to import winter electricity at much higher rates (28–32 c/kWh). This imbalance not only affects individual households but may also contribute to broader grid stress during winter peak periods (Griffith et al. [9]).

Economically, the literature shows mixed evidence. Although declining PV costs and financial incentives improve adoption prospects, weak policy support and poor export returns can undermine the business case. Inconsistent government support reduces homeowner confidence (Alajmi et al., 2018), while the high efficiency of PHs can reduce electricity demand and, therefore, the financial return from SPVS, unless export tariffs, storage, or load-shifting options improve self-consumption benefits. This creates a specific contradiction for SPVS–PH adoption: the same efficiency that makes PHs environmentally attractive may weaken the short-term financial case for adding SPVS.

Behavioural and professional factors also shape adoption but remain less systematically examined. Regulatory ambiguity and inadequate professional training have contributed to architects' reluctance to adopt SPVS–PH [25]. Furthermore, design–as-built discrepancies have been reported to damage client trust [26]. Therefore, SPVS–PH adoption is not only a technical or economic issue; it also depends on professional capability, perceived risk, client priorities, and confidence in long-term performance. The literature shows that SPVS–PH integration is technically promising but economically, behaviourally, and institutionally constrained. The key research gap is therefore not whether SPVS can operate effectively with PHs, but why adoption remains limited despite demonstrated performance benefits.

Although New Zealand is committed to renewable energy transitions, limited research has examined how SPVS are adopted within PHs from a stakeholder-informed and socio-technical perspective. Existing New Zealand studies have advanced understanding of low-carbon housing through life-cycle assessment, environmental-impact assessment, circular construction materials, and energy-demand modelling [11,17,18,27]. However, these studies paid less attention to the behavioural and system-level factors that shape adoption decisions. For example, modelling studies have identified technical challenges such as seasonal SPVS oversupply and winter heating demand mismatch [11,24], while PH-related studies in New Zealand have mainly examined thermal comfort, building performance, or user satisfaction

[28,29]. Similarly, Aigwi et al. [9] examined PH uptake but did not investigate SPVS integration or the broader financial, policy, market, and professional conditions that influence adoption.

Therefore, the key research gap is not only whether SPVS can technically complement PHs, but how technical, economic, behavioural, and institutional conditions shape actual adoption decisions. To address this gap, the study draws on the TAM within a socio-technical transitions perspective. This framing recognises that SPVS-PH adoption is not determined solely by technology, but by the interaction between stakeholder perceptions, technical design, market conditions, policy support, and professional capability [30]. Within this framework, SPVS-PH adoption in New Zealand is treated as the main dependent variable, while the independent variables are grouped into three categories: drivers, barriers, and strategies. These are further organised into four socio-technical dimensions: technical/design, economic/market, behavioural/social, and institutional/policy. The conceptual framing, therefore, suggests that these conditions shape the drivers and barriers influencing SPVS-PH adoption, while enabling strategies can reduce barriers and strengthen adoption pathways.

3. Methodology

3.1. Research approach

The study followed a sequential mixed-methods integration framework. Document analysis first established the SPVS–PH adoption context in New Zealand, while semi-structured interviews identified the key drivers, barriers, and strategies influencing adoption. These interview themes were then converted into survey statements, allowing the quantitative phase to validate and prioritise the qualitative findings. Triangulation was achieved by comparing evidence from documents, interviews, and survey results to determine whether the quantitative rankings supported, extended, or refined the qualitative themes. This approach enables a richer understanding of complex issues by integrating qualitative depth with quantitative breadth [31,32]. Ethical approval was obtained from the Research Ethics Committee of [Institution withheld] (Approval number: [blinded]). Fig. 1 outlines the step-by-step methodology used throughout the research process.

3.1.1. Qualitative methodology: Document analysis & interviews

A sequential qualitative approach, incorporating document analysis and semi-structured interviews, was adopted to investigate the socio-technical dynamics underpinning the SPVS-PH adoption in New Zealand. Document analysis was used to examine adoption trends,

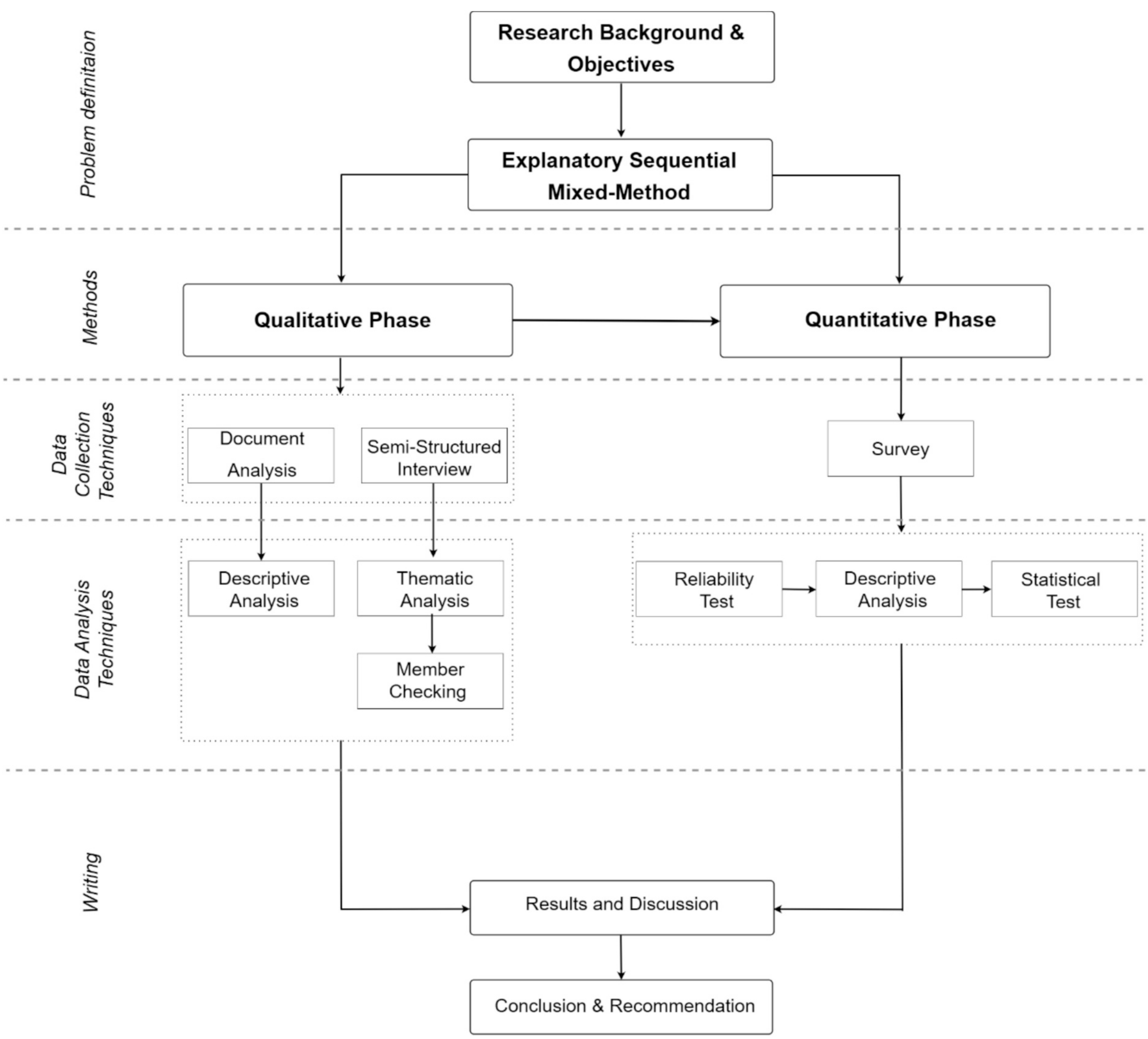

Fig. 1. Research stages for this study.

technology trajectories, and regulatory contexts. As a systematic and interpretive process, document analysis enables researchers to extract meaning and identify patterns across diverse textual sources, thereby enhancing contextual depth and analytical triangulation [33,34].

To enhance transparency in the document analysis, a structured document selection protocol was applied. Documents were included if they were directly related to PH certification, SPVS adoption, residential energy policy, or low-carbon building development in New Zealand. Sources were prioritised based on relevance, credibility, recency, and direct connection to the research questions. Documents were excluded if they were outdated, not specific to New Zealand, not related to SPVS or PHs, or lacked sufficient methodological or institutional credibility. Similar document analysis studies have used structured inclusion and exclusion tables to improve transparency in document selection [35]. Appendix A7 summarises the selection and screening process document.

Key sources included the PHINZ project registries [36], the international Passive House database [37], reports from Sustainable Engineering Ltd [38] and national energy policy documents [5,10,39]. These provided insight into both historical and current patterns in SPVS-PH integration. Recognising inherent limitations such as potential bias or incomplete data[40], document selection was guided by recency, credibility, and relevance, and findings were triangulated with interview data to ensure robustness.

To complement the documentary phase, semi-structured interviews were conducted to capture stakeholder experiences, institutional dynamics, and perceived drivers and constraints. This approach is particularly well-suited to complex, context-sensitive phenomena such as low-energy building transitions[41,42]. Furthermore, semi-structured interviews offer a balance between consistency and flexibility, allowing participants to elaborate on site-specific trade-offs and policy interactions[43]. The participants were selected using purposive and snowball sampling, with inclusion criteria focused on those with over three years' experience in SPVS, pH design, or energy-efficient housing delivery. Publicly available company records were used for initial outreach, followed by participant referrals.

Data saturation was assessed during the interview process by monitoring the emergence of new themes across successive interviews. Saturation is commonly understood as the point at which no substantially new information or themes are identified in the data [44]. Empirical studies suggest that thematic or code saturation can often occur within 9–17 interviews, although deeper meaning saturation may require a larger number depending on the complexity and diversity of the sample [45]. After approximately the 28th interview, recurring themes emerged regarding financial barriers, policy support, technical integration, stakeholder knowledge, and design-stage decision-making. Six additional interviews were conducted to confirm that no substantially new themes were emerging. This indicated that thematic saturation had been reached.

A total of 34 interviews were conducted between March and May 2025: 31 via Microsoft Teams and three by telephone. The participants represented a diverse cross-section of stakeholders, including architects, engineers, consultants, builders, policy advisors, and representatives from energy and industry bodies across different regions (Appendix A1). Interviews were recorded, transcribed verbatim, and analysed using NVivo 14 software, guided by Braun and Clarke's six-phase thematic analysis [46]. Methodological rigour was enhanced through triangulation, member checking, and maximum variation sampling, ensuring credibility, dependability, and transferability [47,48]. Interview insights subsequently informed the development of the quantitative survey instrument.

3.1.2. Quantitative methodology: Survey

Following the qualitative phase of document analysis and stakeholder interviews, a survey was conducted to quantify and validate emergent findings. This explanatory sequential design allowed the development of a theory-driven questionnaire grounded in real-world perspectives, enhancing the depth and generalisability of the results. The survey specifically assessed the perceived significance of key drivers, barriers, and strategies influencing SPVS-PH adoption in the New Zealand residential sector.

The survey instrument comprised two sections. Section one captured participants' demographics, including industry role, firm type and size, years of experience, and prior engagement with SPVS or PH projects. Section two presented 49 statements developed from the interview themes, grouped into three constructs: (i) Drivers, (ii) Barriers, and (iii) Strategies (see Appendices A3–A5). Participants rated their agreement using a 5-point Likert scale, from 1 (Strongly disagree) to 5 (Strongly agree), a format shown to optimise psychometric robustness in built environment research [49].

The eligibility criteria required participants to have at least 3 years' experience in the New Zealand building or energy sector and direct involvement in at least 1 SPVS or PH project. A purposive snowball sampling approach was adopted to ensure relevance and reach [50,51]. The survey was hosted on Qualtrics and distributed via email and LinkedIn between July and September 2025. Ten professionals pretested the instrument to refine language and ensure clarity [52]. Consequently, a total of 96 valid responses were obtained.

3.2. Data analysis

The qualitative data were thematically coded using NVivo 14, encompassing both policy documents and stakeholder interviews. Moreover, the quantitative data were analysed in Statistical Package for the Social Sciences (SPSS) to examine factor importance, with further details provided in the subsequent methodological sections.

3.2.1. Qualitative data analysis

A grounded theory approach was adopted due to the limited empirical research on stakeholder perceptions of SPVS-PH adoption. The approach involves systematic and comparative analysis of qualitative data to identify recurring patterns and develop explanations of emerging phenomena [53]. Documents and interview transcripts were thematically analysed to examine SPVS–PH adoption patterns. NVivo-supported coding began with descriptive coding of key ideas, followed by axial coding to compare, link, and consolidate codes into broader categories and themes [53]. The document review provided contextual baselines, while interview analysis identified key drivers, barriers, and strategies that informed the structure and content of the quantitative survey instrument.

3.2.2. Quantitative data analysis

To analyse the survey data, descriptive statistics (frequencies, percentages, and mean scores) were first applied to summarise responses across the drivers, barriers, and strategies influencing SPVS-PH adoption. Internal consistency was then assessed using Cronbach's alpha, with $\alpha \geq 0.70$ considered acceptable [54]. To evaluate whether mean ratings significantly diverged from neutrality, one-sample *t*-tests were performed against a reference value of 3.0, consistent with five-point Likert scale studies [55]. A significance level of $p < 0.05$ was adopted, reflecting standard analytical convention and the assumption of approximate normality appropriate for Likert-type data [56].

Null hypothesis: There is no significant effect of the identified factors (i.e., drivers, barriers, and strategies) on the adoption of SPVS for PHs in New Zealand.

Decision rule: Reject the null hypothesis if the level of significance $p < 0.05$.

4. Results and discussion

4.1. Document analysis results

The document analysis reviewed certified PH projects and national developments in SPVS uptake across New Zealand. Data were sourced from key national repositories, including PHINZ, iPHA, MBIE, MFAT, the Electricity Authority, and Sustainable Engineering Ltd. These sources offered insights into PH certification types and numbers (2012–2025) and SPVS integration trends.

4.1.1. National Trends and certification dynamics supporting SPVS integration in PHs

The evolving landscape of PH certification offers a compelling lens through which to observe the integration of SPVS. In 2015, the PHI introduced two advanced certification tiers, pH Plus and PH Premium, to supplement the original PH Classic standard [57]. While the Classic model primarily addresses energy efficiency and demand reduction, Plus and Premium extend the criteria to include renewable energy generation. Specifically, pH Plus targets net-zero annual energy consumption, while PH Premium aims for net-positive energy performance [57]. These new tiers have provided a clearer technical and regulatory pathway for SPVS integration within the PH framework. Data from PHINZ [58] indicated that by September 2021, New Zealand had recorded 8 pH Plus-certified homes and 1 pH Premium home. This figure rose to 3 Premium-certified homes by mid-2024 (Sustainable Engineering Ltd., [9] a), demonstrating modest but growing interest in integrating SPVS as a renewable energy solution into high-performance housing projects.

Fig. 2 combines annual certification data from PHINZ, iPHA, and Sustainable Engineering Ltd., highlighting a gradual upward trend in PH uptake from 2016 onwards, with a more notable surge between 2020 and 2023. A simple growth-rate and trend projection analysis was conducted using the annual certification counts shown in Fig. 2. The 2025 value was excluded from the projection because it appears to represent an incomplete year. Between 2012 and 2024, the annual number of certified PH increased from 1 to 17, representing a 1600% increase and a compound annual growth rate of approximately 26.6%. A simple linear projection based on the 2012–2024 trend suggests that annual certifications could reach approximately 22 by 2026 and 29 by 2030 if the observed trajectory continues. However, this projection should be interpreted as indicative rather than predictive, given the small dataset and substantial fluctuations in annual certification numbers. This period of growth is likely attributable to increased policy attention to low-carbon housing and, during the COVID-19 pandemic, heightened awareness of the importance of energy security, indoor air quality, and home resilience [59].

The increase in Plus and Premium certifications also aligns with broader institutional support, such as the Climate Change Response (Zero Carbon) Amendment Act [61] and the Building for Climate Change programme [62], both of which incentivise net-zero-ready housing. However, discrepancies in certification data across databases may result from reporting timelines, particularly between the design and completion stages, necessitating cross-verification to establish accurate trends. Sustainable Engineering Ltd.'s records appeared to offer the most comprehensive coverage.

A slight dip in certifications in the 2023–2024 period may be linked to economic pressures, such as inflation and construction material shortages, as well as the impact of events like Cyclone Gabrielle. For instance, construction costs rose by 7.8% in the year to June 2023 [63], following an 11.5% spike earlier that year [64]. Despite these setbacks, the medium-term outlook remains optimistic, with the increase in Plus and Premium certifications signalling a clear shift toward renewable-ready, high-performance housing models.

The rapid growth of SPVS installations in New Zealand's general housing market provides an important background for analysing their adoption in PHs. For example, the national SPVS capacity grew significantly, reaching approximately 573 MW by December 2024 [10]. This broad trend suggests growing public and market familiarity with solar technology, which could enable its integration into more specialised, low-energy buildings, such as PHs. Although SPVS adoption is expanding rapidly nationwide, the dataset shows that this momentum has not yet fully carried over into the PH sector, where SPVS integration remains relatively limited [14,58]. However, the gradual rise in PH Plus and PH Premium certifications is notable. These certification types explicitly encourage or require on-site renewable generation, meaning that their growth likely reflects increasing recognition among designers and builders of the synergy between SPVS and PHs. In this sense, the expansion of Plus and Premium projects may function as an early signal of emerging integration trends.

This growing alignment at the building level appears to be reinforced by national policy. For instance, the ambitious government targets 100% renewable electricity by 2030 and 50% by 2035 [5], which can be seen as creating a supportive, long-term policy environment. Therefore, these frameworks create a supportive policy environment that aligns individual building performance, such as SPVS-PH integration, with national decarbonisation and energy resilience objectives.

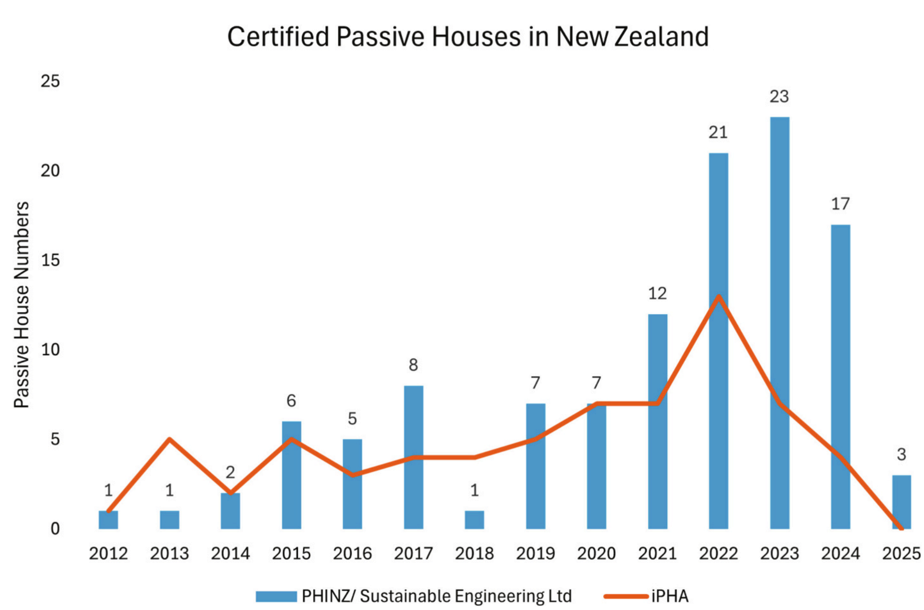

Fig. 2. Historical progression of Certified PH in New Zealand and SPVS-PH (Plus/Premium). Source:([14,58]*; Passive House Database (2021);* Passipedia [57]*;* [60].

4.2. Interview results

Findings from the interview are categorised into three key themes: drivers, barriers, and strategies for SPVS-PH adoption, as illustrated in Fig. 3. Further details follow in subsequent sections.

4.2.1. Drivers for SPVS-PH adoption

The 34 participants identified key drivers for SPVS-PH adoption in New Zealand, centring on cost savings, energy autonomy, and sustainability. The technical–financial synergy of SPVS-PH was widely emphasised. Broader social motivations also emerged, as *P25* remarked, "*SPVS-PH is more than a technical solution; it promotes dignity and energy fairness*." These findings were grouped into five thematic categories: Economic Benefits, SPVS-PH Design Synergy, Energy Independence, Environmental Sustainability, and Social Benefits (Appendix A2 and A6).

4.2.1.1. Economic benefits. Economic considerations emerged as a dominant driver of SPVS-PH adoption in New Zealand, with 17 participants linking adoption to rising electricity prices, improved affordability, and long-term operational savings. The participants did not frame SPVS simply as an additional technology, but as a way to reduce exposure to increasing grid electricity costs and improve the operating economics of high-performance homes. This aligns with studies showing that electricity prices, system costs, payback expectations, and financial returns are important determinants of residential SPVS adoption [65]. Five participants noted that rising electricity prices had increased the attractiveness of SPVS (**P5, P6, P10, P13, P15**), while others emphasised that declining PV costs have strengthened its economic appeal (**P1, P4, P29**). As **P4** explained, PV panels are now "*a tenth of the cost they were five years ago*," aligning with evidence that falling SPVS costs can support adoption [66].

The economic value of SPVS-PH integration was also linked to PHs' low operational demand. Participants suggested that because PHs require less energy than conventional homes, SPVS can offset a larger share of household demand without the need for oversized systems. This is consistent with passive building research showing that low-energy building design reduces operational energy demand and enhances the feasibility of integrating renewable energy [67]. Moreover, SPVS electricity costs approximately 6 cents/kWh, considerably lower than grid rates of \$0.35–\$0.45/kWh (**P5**). **P5** further advised that adoption must remain cost-efficient, analogising: "*It's like buying a fuel-efficient car, then choosing the most expensive petrol*," highlighting how continued grid dependency can undermine economic performance. The findings suggest that SPVS-PH adoption becomes financially attractive when declining system costs, avoided grid dependence, long-term savings, and potential export income are balanced against upfront investment.

4.2.1.2. SPVS-PH design synergy. Design synergy emerged as a key driver of SPVS-PH adoption, with 16 participants describing the two

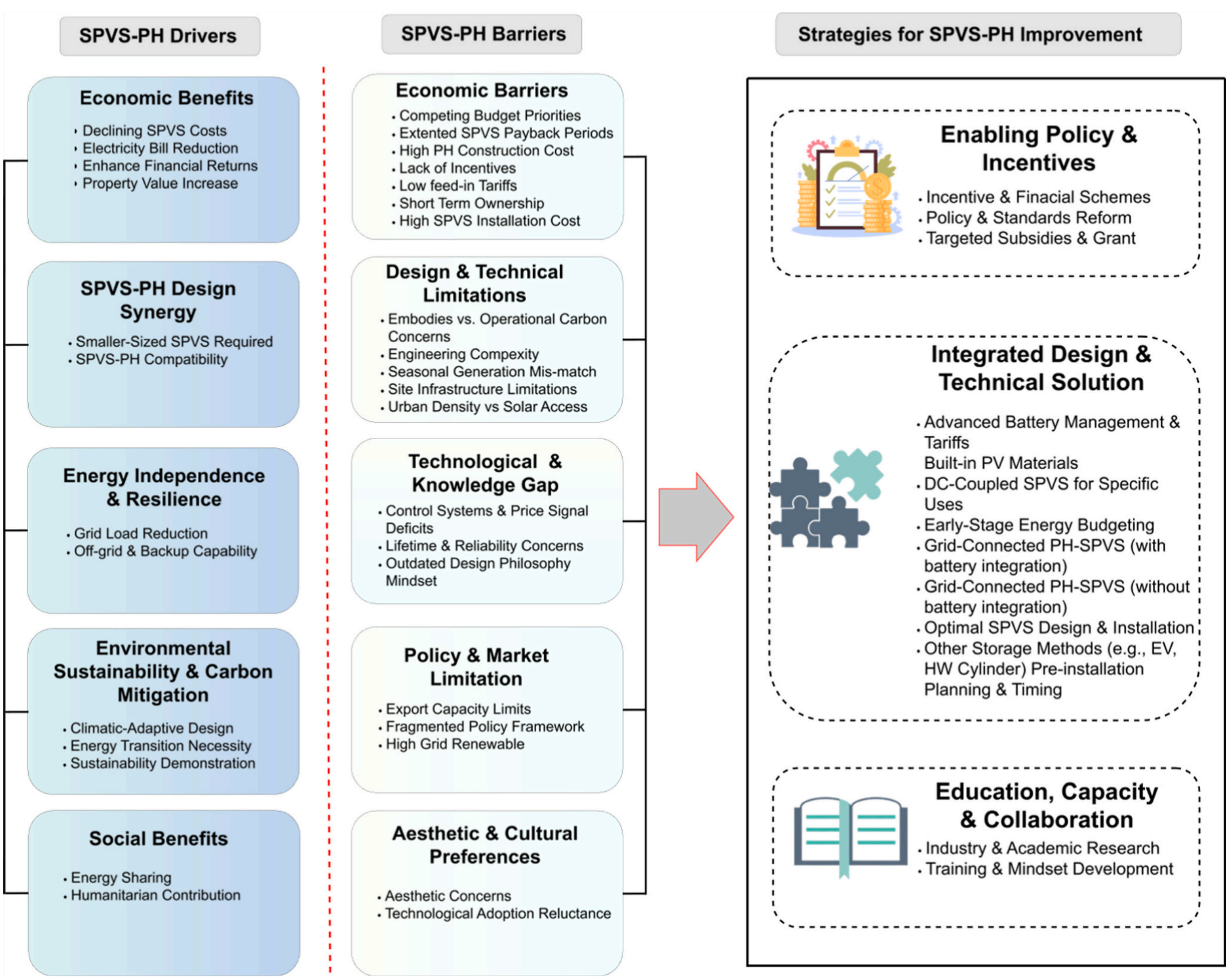

Fig. 3. Schematic diagram of the stakeholder-informed model of SPVS-PH adoption.

systems as technically and conceptually complementary. Participants viewed SPVS integration as a natural extension of PH design because both aim to reduce energy demand, improve efficiency, and support low-carbon living. His aligns with research showing that passive building strategies and renewable energy integration are complementary pathways for reducing building-sector energy use and emissions [68]. Combining SPVS with PHs is a "*logical step*" because both systems share the objective of improving energy autonomy and reducing carbon emissions (**P33**).

The strongest area of synergy relates to the low baseline energy demand of PHs. Participants explained that because PHs require substantially less energy for heating and cooling than conventional homes, SPVS can meet a larger proportion of household demand without requiring oversized arrays. "*PH do not need such a large array*," with modest 3–5 kW systems often considered adequate for typical PHs (**P16**). This suggests that PH efficiency can improve the cost-effectiveness of SPVS by reducing system size while maintaining meaningful energy contribution.

Participants also linked design synergy to architectural and operational features. PHs are often designed with simplified building forms, good solar orientation, and reduced shading, which can improve PV placement and yield (**P2, P4, P5, P25, P27**). Their stable energy profiles may also flatten demand curves and improve self-consumption, reducing pressure on the grid (**P15, P22, P27**), consistent with previous building performance research [69]. In addition, participants noted that thermal mass can store solar gains and reduce reliance on battery storage, supporting findings on thermal energy storage in autonomous buildings [70].

4.2.1.3. Energy independence and resilience. Energy independence and resilience emerged as a recurring driver of SPVS-PH adoption, with 17 participants linking integration to household autonomy, backup capacity, and reduced dependence on the central grid. Participants viewed SPVS-PH systems as particularly valuable in contexts where electricity prices are rising, grid reliability is uncertain, or households seek greater control over their energy supply. Rather than framing SPVS solely as a cost-saving measure, participants viewed it as part of a broader resilience strategy to enhance household and community preparedness.

The greatest resilience benefit is SPVS's ability, particularly when combined with battery storage, to support households during outages or emergencies. Participants noted that this could be especially important in remote or disaster-prone regions, where grid restoration may be delayed, and households need reliable backup power (**P7, P15, P20, P21**). This aligns with research showing that decentralised energy systems can strengthen collective disaster preparedness and reduce reliance on vulnerable centralised infrastructure [71].

Participants also connected energy independence to broader grid benefits. By reducing grid electricity demand during peak periods, SPVS-PH systems were seen as contributing to grid stabilisation and long-term energy security (**P9, P20, P22, P28, P32**). The low energy demand of PHs further enhances this benefit because smaller PV and battery systems may be sufficient to maintain essential household functions during disruptions. In this sense, participants positioned SPVS-PH integration as a future-oriented solution that supports household autonomy, community resilience, and national energy transition goals, consistent with New Zealand's long-term energy strategy [72].

4.2.1.4. Environmental sustainability and carbon mitigation. Environmental sustainability and carbon mitigation emerged as a major driver of SPVS-PH adoption, with participants linking integration to low-carbon living, reduced reliance on fossil fuels, and national decarbonisation goals. Rather than viewing SPVS solely as an energy-cost solution, participants framed it as a visible expression of environmental responsibility and a practical pathway to reducing household operational emissions. This was particularly evident among PH clients, who were described as already motivated by energy efficiency and therefore more likely to view SPVS as a logical extension of their sustainability values (**P13, P17, P20, P21, P34**).

Participants also challenged assumptions that New Zealand's solar potential is too limited for meaningful residential generation. Several noted that, despite regional variation, solar resources are generally sufficient to support wider SPVS deployment (**P2, P3**). This suggests that adoption barriers may be less about solar availability and more about design, cost, policy, and stakeholder confidence. In addition, participants connected SPVS-PH integration to long-term resilience by emphasising the importance of fossil-fuel-free self-supply and energy neutrality (**P6, P8, P14, P17**). The findings indicate that SPVS-PH adoption supports both direct climate mitigation and the development of resilient low-carbon infrastructure, aligning with research on New Zealand's just and sustainable energy transition [73].

4.2.1.5. Social benefits. Social benefits emerged as a complementary driver of SPVS-PH adoption, with participants linking integration to household well-being, energy equity, and community resilience. Rather than viewing SPVS-PH systems only through technical or financial lenses, participants framed them as part of a broader transition toward healthier, more secure, and socially inclusive housing. This was particularly evident in comments that associated reduced energy costs with lower household stress and improved comfort, especially in colder regions or underserved communities (**P10, P15, P25, P32**).

Participants also connected SPVS-PH adoption to energy justice. Decentralised generation was seen as a way to reduce exposure to rising electricity prices and improve household control over energy use. However, participants recognised that these benefits may remain unevenly distributed if SPVS-PH systems are accessible mainly to higher-income homeowners (**P24, P28, P30**). This suggests that social benefits depend on whether policy and financing mechanisms make adoption more inclusive.

A further social dimension was the potential for energy sharing and civic responsibility. Participants suggested that surplus electricity could support broader community resilience, with one participant describing this as a form of "energy responsibility" (**P25**). The findings indicate that SPVS-PH adoption can contribute to well-being, energy awareness, and inclusive low-carbon transitions when supported by equitable access and community-oriented policy design, consistent with literature on distributed energy systems and socially inclusive transitions [74].

4.2.2. Barriers to SPVS-PH adoption in New Zealand

All 34 participants identified barriers to SPVS-PH adoption, including high upfront costs and inadequate incentives; technical and site-specific issues; knowledge gaps among stakeholders; and design norms that prioritise non-renewable energy sources. Further barriers were policy limitations and aesthetic concerns in sensitive areas. As ***P14*** noted, "*SPVS is always the first thing cut when budgets tighten.*" These barriers are categorised as follows: Economic, Technical, Knowledge-Based, Policy & Market, and Aesthetic & Cultural (Appendix A2).

4.2.2.1. Economic barriers. Cost-related challenges were the most cited barrier, with 30 of 34 participants identifying high upfront costs, limited incentives, and modest short-term returns as major constraints. These issues were not viewed in isolation but as interacting financial pressures that shape design-stage decision-making. Participants noted that when budgets tighten, SPVS is often among the first elements removed or deferred (**P13, P14, P15, P28, P30**). This suggests that SPVS is still frequently treated as an optional enhancement rather than an integral component of low-energy housing. A recurring concern was that the economic appeal of SPVS is weakened by the absence of supportive feed-in tariffs within New Zealand's market structure (**P14, P30,** (Griffith et al. [9])). Participants argued that symmetrical tariffs, in which export rates are set closer to peak import rates, would make uptake considerably more attractive (**P15, P28**).

The interviews also revealed a specific economic contradiction within PHs. Their high efficiency lowers energy demand, but this can reduce financial returns from SPVS by limiting self-consumption under poor export tariff conditions (**P32, P34**). Moreover, the short average duration of homeownership in New Zealand further complicates the cost-benefit logic, as "*people don't stay in homes long enough*" to realise full returns (**P28**). Economic barriers, therefore, extend beyond upfront affordability to include payback uncertainty, tariff design, and ownership patterns. Equity concerns were also prominent, with participants noting that SPVS-PH benefits may primarily accrue to affluent homeowners while those most in need are priced out (**P24**). Maintenance costs, such as battery replacement every decade, further challenge long-term viability (**P26**).

4.2.2.2. Design & technical limitations. Sixteen participants raised design and technical challenges associated with SPVS-PH integration, including seasonal energy mismatch, site-specific constraints, system sizing, and installation quality. Rather than being isolated technical issues, these constraints interact to affect system performance, cost-effectiveness, and long-term reliability. A common concern was the mismatch between peak solar generation and residual household demand, particularly during winter when solar output is lower but energy needs may increase (**P1, P18, P34**). Bridging this gap requires either battery storage, demand-side management, or careful PV sizing (**P34**), reflecting challenges already identified in New Zealand's temperate climate [11].

Participants also emphasised that technical feasibility depends strongly on site and building conditions. Retrofit scenarios and urban constraints can prevent optimal north-facing orientation, while overshadowing and insufficient roof capacity reduce solar yield (**P10, P16, P31**). Poorly positioned systems may spend "*half the day in the shade*," limiting performance and weakening the economic case for adoption (**P31)**. These constraints suggest that SPVS-PH integration is most effective when considered early in the design process rather than treated as a later add-on.

Beyond operational performance, participants raised concerns about lifecycle and durability. These included the limited availability of raw materials and high energy demands of SPVS production (**P12**), limited end-of-life disposal options (**P24**), and technical risks in high-exposure environments. Poor installation practices in areas prone to strong winds or heavy rainfall may compromise roof integrity over time (**P17, P22**). The findings show that design and technical barriers extend beyond PV performance to include site suitability, lifecycle impacts, installation quality, and long-term system resilience, reinforcing the need for lifecycle-based assessment [75,76].

4.2.2.3. Technological and knowledge gap. Eleven participants identified technological and knowledge gaps as barriers to SPVS-PH adoption, particularly regarding professional training, design philosophy, system integration, and user understanding. These issues appear interconnected, as limited technical knowledge can influence design decisions, erode client confidence, and compromise the quality of system integration. The participants viewed the predominant "fabric-first" approach within the PH standard as important for energy efficiency, but they also suggested that it can marginalise renewable energy when designers lack sufficient SPVS training or integration experience (**P1, P5, P33**). As a result, SPVS may be undervalued during early planning rather than considered as part of a holistic low-carbon design strategy. This concern aligns with MBIE [77] call for improved guidance and education to support low-carbon building practice.

Participants also raised concerns about the performance and lifecycle reliability of technology. **P1** questioned the longevity of cheaper panels, stating, "*You'd be lucky to get 20 to 25 years of meaningful energy*," while others noted concerns about embodied energy and system efficiency (**P6, P12**). These concerns reinforce the need to consider lifecycle performance alongside upfront cost and operational savings [62]. Integration challenges, including inadequate control systems, limited grid data access, and the need for smarter battery management, further complicated adoption (**P2**). Fragmented knowledge among designers, installers, and homeowners can lead to decisions based on assumptions rather than robust performance information (**P8, P9**).

4.2.2.4. Policy & market limitation. Nine of the 34 participants identified policy and market limitations as barriers to SPVS-PH adoption. These concerns were not limited to the absence of regulation; they also reflected broader uncertainty about how policy, market rules, and building standards support SPVS adoption. Participants noted gaps in policy coherence, including outdated frameworks, limited regulatory alignment, and the absence of compulsory SPVS provisions within national building certification schemes (**P1, P3, P5, P6, P10**). Policy inertia, rather than technological readiness, was viewed as a key constraint, with government action perceived as fragmented, limited to isolated initiatives, rather than comprehensive support (**P6, P28**).

Moreover, export restrictions further weakened the market case for adoption. Participants noted that the standard 5 kW export cap can deter investment in larger systems by limiting economic returns, particularly for PHs that may generate surplus electricity because of their low energy demand (**P2, P5, P21**). This suggests that regulatory settings may reduce the value of technically efficient SPVS-PH systems if households cannot fully benefit from exported energy. Raising export caps and easing grid restrictions could therefore improve uptake and strengthen household participation in energy markets [78,79].

Participants also argued that the absence of SPVS requirements in other major New Zealand building standards may contribute to its being treated as an optional add-on (**P5, P10**). However, the findings also suggest that mandates should be carefully designed, as poorly targeted requirements could encourage unsuitable installations and undermine performance or public confidence (**P31**).

4.2.2.5. Aesthetic & cultural preferences. Aesthetic and cultural preferences were identified by nine participants as barriers to SPVS-PH adoption. These concerns were not simply about visual appearance but also reflected broader expectations regarding architectural identity, property value, and the acceptability of visible energy technologies in residential design. Participants noted that some homeowners are reluctant to install SPVS because they perceive panels as visually intrusive or inconsistent with traditional roof forms. As **P4** observed, "*people don't like the look of solar panels on the roof*," suggesting that aesthetic preferences can influence willingness to adopt SPVS even when technical or environmental benefits are recognised.

The findings also indicate that cultural perceptions can shape both client and professional decision-making. Some homeowners were described as holding conservative views about residential appearance, with **P7** noting that "*solar panels are seen as detracting from property values*." This concern may be reinforced by architectural practices that prioritise exterior finishes over energy performance, particularly where designers dislike the appearance of SPVS or do not actively recommend it to clients (**P5, P14**). Therefore, aesthetic resistance can become embedded in early design choices rather than emerging only at the installation stage.

However, participants also noted design flexibility. PHI allows rooftop, ground-mounted, or façade-integrated systems that meet renewable energy targets (**P8**). This suggests that wider adoption may depend on improving design integration and expanding the range of visually acceptable options, such as BIPV.

4.2.3. Strategies to improve SPVS-PH adoption

The participants proposed strategies to accelerate SPVS-PH adoption, centred on enabling policy and incentives, integrated design and technical solutions, and enhanced education and collaboration. Key recommendations included financial subsidies, designing for solar readiness from the outset, and promoting full electrification to maximise on-site consumption. This approach reframes the grid as a "virtual battery" for equitable energy sharing. They stressed that overcoming barriers requires parallel efforts in policy, design, and knowledge, as detailed in Appendix A2.

4.2.3.1. Enabling policy and incentives. Participants recommended policy and financial interventions as central strategies for accelerating SPVS-PH adoption. Although declining technology costs were acknowledged, participants argued that cost reductions alone are insufficient without stable policy support, accessible finance, and clearer regulatory pathways. Upfront financial support and stronger regulatory frameworks were therefore considered necessary to overcome structural barriers to adoption (**P1, P14, P18**). Moreover, improved financing mechanisms, including green loans and Power Purchase Agreements, were identified as practical tools to reduce the initial cost burden and broaden participation (**P2**).

Participants also linked policy interventions to market certainty and to design-stage decision-making. Several advocated mandatory SPVS inclusion in new residential buildings, drawing on international examples such as California's mandate (**P13**), while others suggested integrating SPVS across all PH categories to improve grid flexibility and seasonal resilience (**P27**). Simplified grid connection protocols and lower compliance costs, similar to the German model, were also proposed to reduce administrative barriers (**P8**).

Financial incentives were seen as most effective when linked to equity and early-stage procurement. Participants recommended expanded green finance, including zero-interest loans, bank-provider partnerships, and loan eligibility that supports design-stage SPVS planning rather than only post-construction installation (**P14, P15, P16, P18, P30**). Reforming feed-in tariffs was also considered important because low export values undermine investment confidence (**P27, P30**). Participants viewed enabling policy as a combined package of incentives, tariff reform, simplified regulation, and targeted subsidies for landlords and build-to-rent developers to ensure broader socio-economic access (**P1, P9, P15, P24**).

4.2.3.2. Integrated design & technical solution. Participants emphasised the importance of integrated design and technical solutions for advancing SPVS-PH adoption in New Zealand. Rather than treating SPVS as a later retrofit or optional add-on, participants viewed early design integration as the point where technical performance, cost efficiency, and long-term usability are most effectively determined. A recurring view was that SPVS should be considered during the early design phase, as this allows for more efficient planning of orientation, roof form, structural capacity, and electrical pathways (**P5, P7, P8, P17**).

Proactive design measures included optimised roof orientation, pre-installation of conduits, and structural allowances for future SPVS installation (**P9, P17**). Even small provisions, such as pre-installed ducts, were framed as low-cost measures that could reduce future retrofit barriers (**P7**). Optimal solar yield can be achieved with north-facing roof slopes pitched at 30°–35°, supporting the importance of solar-ready design [80]. As **P8** stated, "*designing to be solar-ready makes a lot of difference*."

Participants also linked technical integration to more effective use of the generated electricity. Demand-side solutions, including heat pumps, water diverters, hot water cylinders, and EV charging, were recommended to improve self-consumption and reduce reliance on exported electricity. Hot water cylinders and heat pumps were described as "*thermal batteries*," particularly when supported by automated controls (**P2, P18**). EV readiness and vehicle-to-grid pathways were also viewed as future-proofing options (**P2, P17, P26**). Some participants favoured grid-tied systems, describing the grid as a "*virtual battery*" that supports flexibility, equity, and wider social acceptance (**P13, P26**). Participants stressed that integrated design must be supported by commissioning, performance modelling, and user guidance to ensure reliability and trust (P1, P10, P20, [80]).

4.2.3.3. Education, capacity-building & collaboration. Participants proposed education, capacity building, and collaboration as strategic levers to advance SPVS-PH integration in New Zealand. These recommendations show that adoption depends not only on the availability of technology but also on the ability of homeowners, professionals, and institutions to effectively understand, communicate, and apply SPVS-PH knowledge. Twelve participants emphasised the need to improve homeowner energy literacy through targeted public engagement, enabling clients to understand the long-term financial, environmental, and resilience benefits of SPVS-PH systems (**P2, P15, P20, P25, P33**).

Professional capacity-building was also viewed as central to translating awareness into practical implementation. Participants recommended updating industry training to reflect current technologies and embedding SPVS-related competencies into the education of designers, builders, and energy advisors (**P5, P20**). These recommendations align with the workforce development objectives of MBIE [81]'s Building for Climate Change Programme, which calls for comprehensive upskilling to support low-carbon building transitions.

Participants further stressed that early intervention is crucial, as introducing SPVS at the conceptual design stage can increase the likelihood of its inclusion in final builds (**P20**). In this sense, education and design integration are closely linked: when professionals and clients understand SPVS early, it is less likely to be treated as a later retrofit or optional add-on. Finally, participants called for stronger cross-sector knowledge exchange to ensure that academic findings, government guidance, and field experience are better integrated into lifecycle-oriented guidance for installers and project teams (**P6, P26**).

4.3. Survey results

To ensure robust quantitative analysis of factors influencing SPVS-PH adoption, initial data screening was conducted to validate the quality of responses. Following the guidelines of Barkokebas et al. [82]. The dataset was examined for missing values, multicollinearity, and normality, and 96 valid responses were retained. Furthermore, the reliability assessments confirmed the internal consistency of the thematic constructs, drivers, barriers, and strategies. Cronbach's Alpha coefficients were calculated, showing an overall alpha of 0.866, with values of 0.851 for drivers, 0.860 for barriers, and 0.812 for strategies. These exceeded the 0.7 threshold, indicating high reliability [83].

4.3.1. Demography and professional profile of participants

The survey was administered via email and LinkedIn from 18th August to 10th October 2025. Of 98 responses received, two were excluded due to a lack of relevant experience in PHs, low-energy building, or SPVS, leaving 96 for analysis. The participants represented a broad cross-section of New Zealand's building and energy sectors, including engineering, architecture, construction, and sustainability policy.

Over 46% had more than 15 years of experience in the field, with another 33% having 6–15 years, indicating a highly experienced pool. Most were directly involved in sustainable residential projects, particularly PHs and SPVS. The participants came primarily from small firms, with the remainder from medium or large organisations. Appendix B1 summarises their demographics and backgrounds.

4.3.2. Survey participants' perspectives on SPVS-PH adoption

4.3.2.1. SPVS-PH adoption drivers. Data concerning SPVS-PH adoption drivers were analysed using a one-sample *t*-test (Fig. 4, Appendix B2).

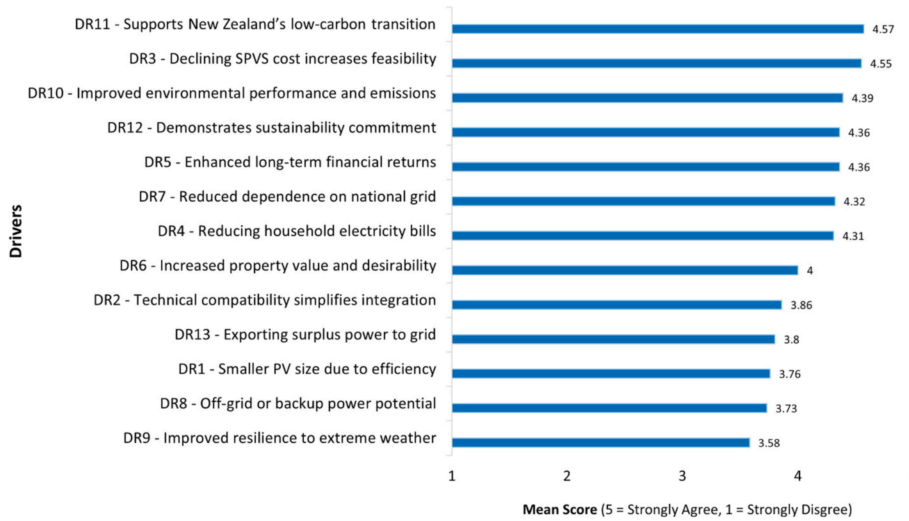

Fig. 4. Mean importance ratings of Drivers for SPVS–PH adoption.

High mean scores for DR11 ("Supports NZ's low carbon transition", mean = 4.57), DR3 ("Declining SPVS cost", mean = 4.55), and DR10 ("Improved environmental performance", mean = 4.39) indicate strong consensus that these are the most compelling motivations, based on a 1–5 Likert scale. Participants view both environmental and financial advantages as critical drivers. This prioritisation is consistent with previous findings; for example, Schelly and Letzelter [84] found environmental motivations slightly outweighed financial ones when upfront costs were seen as manageable.

In contrast, the lowest-ranked drivers, DR9 ("Improved resilience to extreme weather", mean = 3.58), DR8 ("Off-grid or backup potential", mean = 3.73), and DR1 ("smaller PV size due to efficiency", mean = 3.73), received weaker agreement. Although statistically significant ($p < 0.001$), they are seen as less significant. This pattern aligns with findings that energy security and return on investment are greater drivers than backup features [85], and that technical and financial factors typically take priority over resilience [86]. Thus, while off-grid potential motivates in areas with unstable grids, resilience alone is unlikely to drive widespread adoption without stronger technical and financial drivers.

4.3.2.2. SPVS-PH adoption barriers. Analysis of SPVS-PH adoption barriers using a one-sample t-test identified the most significant barriers (Fig. 5, Appendix B3). BR7 ("budget priorities hinder SPVS installation", mean = 4.09), BR11 ("low solar energy buy-back rates", mean = 3.87), and BR10 ("lack of financial incentives", mean = 3.78) were the most strongly agreed-upon barriers. These high scores indicate a clear consensus that financial constraints, tight budgets, inadequate incentives, and poor export tariffs pose major challenges to adoption. The participants suggest that without sufficient resources, supportive policies, and fair compensation for surplus energy, uptake is likely to stagnate.

These findings align with existing research on energy-efficient buildings and renewables. For instance, extended payback periods and unstable incentive frameworks are persistent deterrents to residential SPVS [87]. Similarly, weak feed-in tariffs undermine the economic appeal of integration [88], reinforcing that financial viability is a primary concern even when technical feasibility is high.

In contrast, BR1 ("visual impact", mean = 2.4), BR4 ("technical integration complexity", mean = 2.65), and BR17 ("lifespan and reliability concerns", mean = 3.00) ranked lowest. BR1 had a significantly positive t-value ($p < 0.001$), showing strong disagreement that

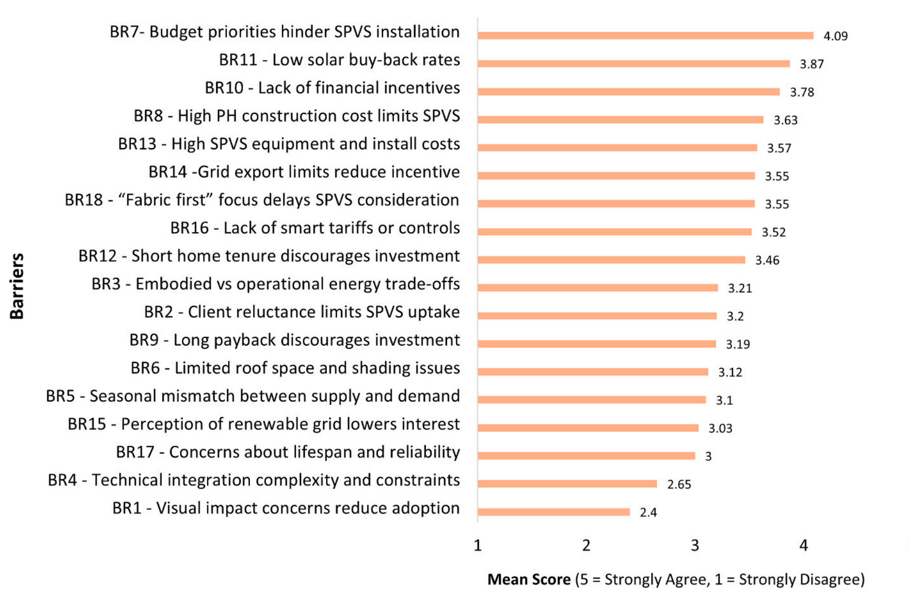

Fig. 5. Mean importance ratings of Barriers for SPVS–PH adoption.

aesthetics are a major barrier, suggesting such concerns are secondary. Several factors, including BR5 ("seasonal mismatch", mean = 3.1) and BR15 ("belief that the grid is already renewable", mean = 3.03), had non-significant *p*-values and neutral means, indicating divided views among participants.

4.3.2.3. Strategies for enhancing SPVS-PH adoption. The results for SPVS-PH adoption strategies are shown in Fig. 6 and Appendix B4. The high mean scores for ST16 ("optimised design and installation", mean = 4.54), ST14 ("batteries for resilience and grid support", mean = 4.53), and ST1 ("government incentives", mean = 4.49) demonstrate very strong agreement that these are the most effective strategies for accelerating adoption. These findings imply that building professionals should prioritise early optimisation, while policy regulators should support stable, targeted incentives.

Other studies support this: well-designed subsidies significantly increase residential SPVS uptake [89], and battery storage with time-of-use pricing enhances household economics and grid interaction [90]. Combining PV with a battery also boosts self-sufficiency and community resilience, validating strong agreement with ST14 [91].

High agreement with ST13 ("early energy modelling", mean = 4.39) and ST4 ("targeted subsidies", mean = 4.39) underscores the importance of technical foresight and financial support, complementing research on strategic subsidies for low-carbon outcomes [91]. The mean scores for ST12 ("mandating SPVS-ready features", mean = 3.41), ST11 ("adopting BIPV", mean = 3.52), and ST15 ("grid-only SPVS", mean = 3.58) indicate more cautious support. While mandates can drive change, they face feasibility constraints, and BIPV remains cost-intensive [92]. The findings imply that economic viability, design optimisation, and storage integration are the most decisive strategies for scaling SPVS-PH adoption.

4.4. Comparison of findings with existing literature

Table 1 compares the main findings of this study with those in the existing literature. The comparison highlights areas of agreement, contradiction, and extension. While previous studies have primarily demonstrated the technical feasibility and environmental benefits of SPVS-PH integration, the present study provides stakeholder-based evidence on the financial, policy, behavioural, and design factors that shape real-world adoption in New Zealand.

5. Discussion

This study advances SPVS-PH adoption research by interpreting adoption as both a behavioural acceptance issue and a socio-technical transition challenge. From the Technology Acceptance Model (TAM), adoption is influenced by stakeholders' perceptions of usefulness and ease of use [15,93]. The survey results show strong perceived usefulness, particularly in support of New Zealand's low-carbon transition, declining SPVS costs, and improved environmental performance (see Fig. 7). These findings align with residential PV adoption studies, which show that perceived environmental benefits, financial returns, and policy support are important predictors of solar uptake [87,89].

However, the findings also show that perceived usefulness alone is insufficient. Ease of implementation remains constrained by budget priorities, low buyback rates, weak incentives, technical integration challenges, and limited professional expertise. This supports the argument that adoption depends not only on whether a technology is seen as beneficial, but also on whether stakeholders perceive it as financially, technically, and institutionally feasible [94,95]. The socio-technical transitions perspective further explains why SPVS-PH adoption remains limited despite its technical potential. Socio-technical theory suggests that low-carbon technologies diffuse through interactions between technologies, users, markets, regulations, infrastructures, and professional practices [96]. In this study, SPVS-PH adoption is shaped by the interactions among PH design principles, household energy demand, grid export arrangements, financing mechanisms, building regulations, and professional capabilities. This is consistent with previous evidence that technical feasibility does not automatically produce market uptake when institutional and behavioural conditions are weak [12].

A key contradiction identified in this study is that PH efficiency both supports and constrains SPVS adoption. Technically, PHs' low energy demand makes SPVS integration attractive, as smaller SPVS can offset a larger share of household electricity use. This is consistent with modelling studies that show strong emission-reduction potential for SPVS-PH configurations [20]. Economically, however, lower household demand can reduce self-consumption and weaken financial returns

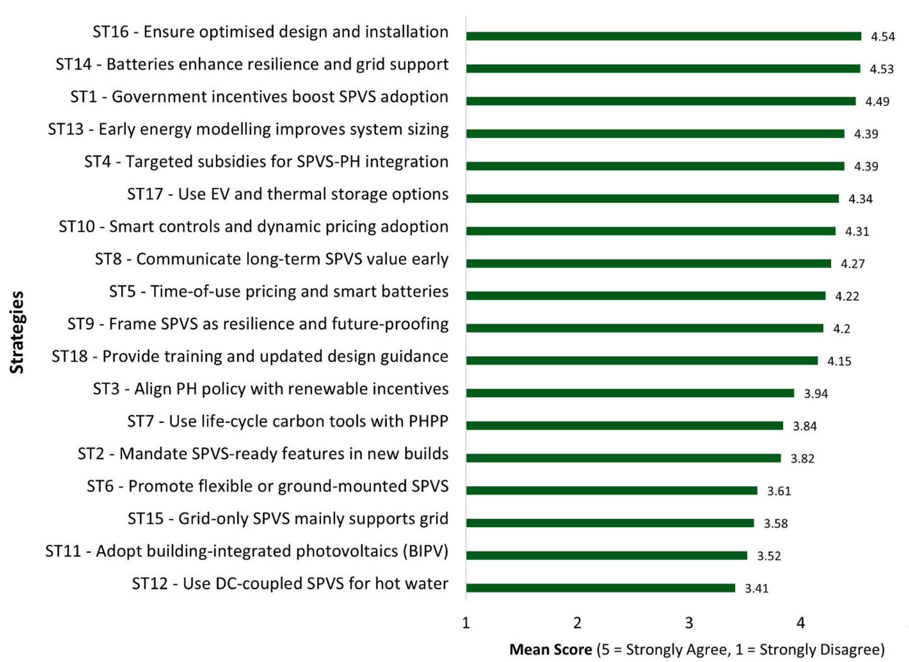

Fig. 6. Mean importance ratings of the strategies for SPVS–PH adoption.

Table 1
Comparison of Current Findings and Previous Studies.

Key finding from this study	Existing outcome in literature	Comparison and contribution
SPVS-PH adoption in New Zealand is emerging but remains limited compared with wider residential SPVS uptake.	Previous studies show that SPVS-PH integration is technically feasible and can support low-carbon housing, but much of the literature is modelling-based rather than adoption-focused ([19]; [20]).	This study extends existing technical evidence by showing that real-world adoption remains limited despite technical feasibility.
The strongest drivers were support for New Zealand's low-carbon transition, declining SPVS costs, and improved environmental performance.	Previous studies identify environmental benefits, cost reduction, and renewable energy transition goals as important drivers of residential SPVS adoption ([22]; [12]).	The findings are consistent with the literature but provide New Zealand-specific stakeholder and survey evidence.
Budget priorities, low buy-back rates, and lack of financial incentives were the most significant barriers.	Existing studies show that high upfront cost, weak incentives, and poor export compensation limit residential solar uptake (Griffith et al. [9]; [11]).	This study confirms these barriers in the SPVS-PH context and shows that they are especially important where PHs already have low energy demand.
PH efficiency creates design synergy with SPVS, as lower demand can enable smaller SPVS.	Prior SPVS-PH studies emphasise the technical compatibility of PV systems with low-energy buildings ([19]; [20]).	This study supports previous technical findings but adds stakeholder evidence on how this synergy influences adoption decisions.
PH efficiency may also reduce financial returns from SPVS where export tariffs are low.	New Zealand studies highlight seasonal mismatch between solar generation and winter electricity demand ([11]; [24]).	This study identifies a technical-economic contradiction: PH efficiency supports smaller systems but may weaken the financial case under low buy-back rates.
Optimised SPVS design, battery integration, and government incentives were the highest-ranked strategies.	Previous studies suggest that storage, supportive policies, and integrated design can improve the adoption of renewable energy in buildings ([22]; [70]).	This study prioritises these strategies based on stakeholder survey evidence and demonstrates their relevance to the New Zealand PH sector.
Aesthetic concerns appeared in interviews but were less dominant than financial and policy barriers.	Previous research suggests that design preferences and architectural acceptance can influence uptake of renewable technologies [25].	This study shows that aesthetics matter, but may be less influential than economic and policy barriers in the New Zealand SPVS-PH context.

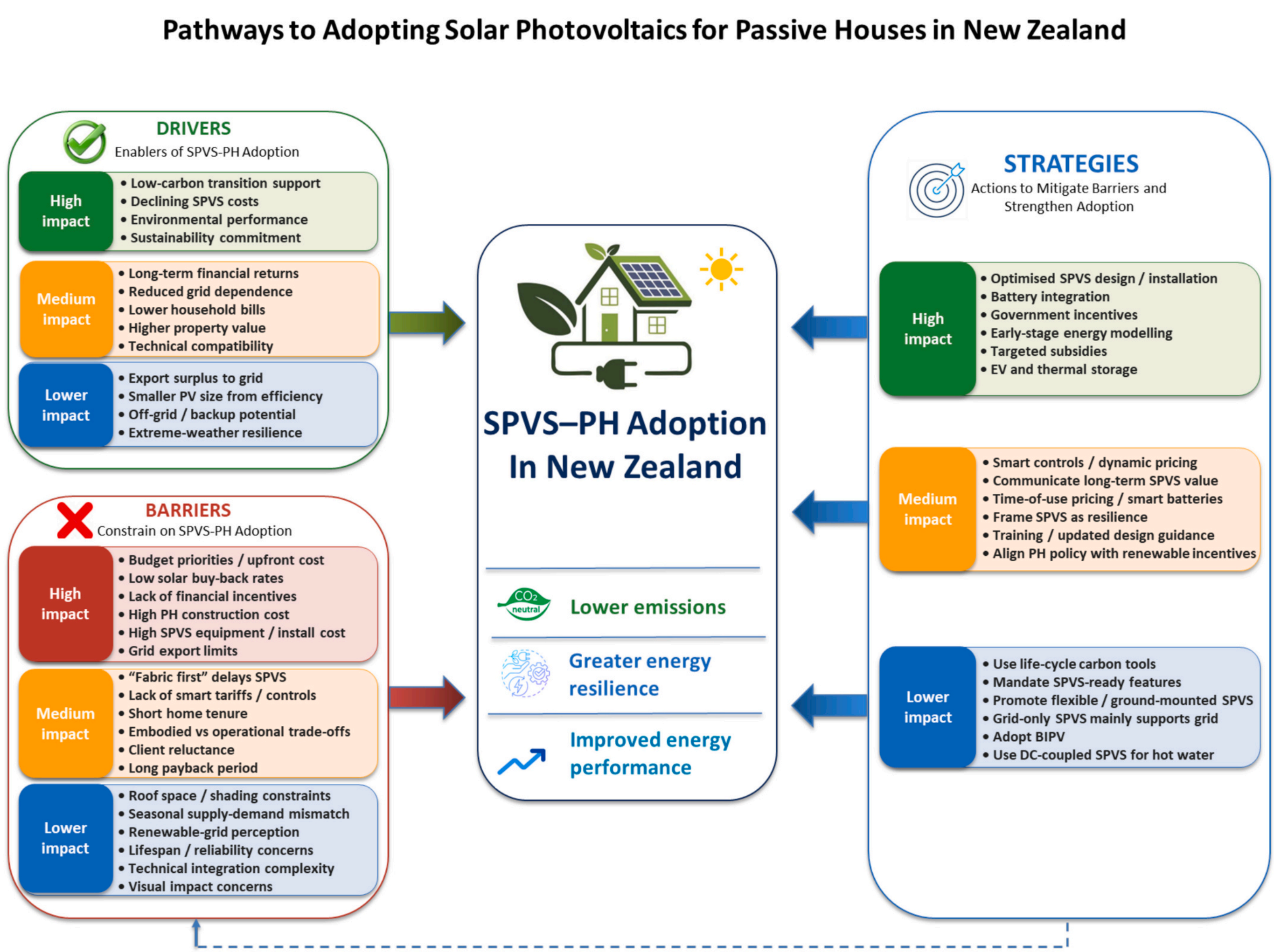

Fig. 7. Weighted framework of factors influencing SPVS-PH adoption in New Zealand.

when export tariffs are low. This finding extends New Zealand studies that highlight a seasonal mismatch between solar generation and winter demand in low-energy housing [11,24]. Therefore, SPVS-PH adoption involves a techno-economic tension: the same efficiency that makes PHs environmentally valuable can undermine the short-term economic case for solar unless supported by storage, load shifting, or fairer export arrangements.

The study also reveals contradictions between qualitative and quantitative findings. Aesthetic concerns emerged in the interviews, with some participants viewing SPVS as visually intrusive or inconsistent with traditional residential design. However, visual impact ranked low in the survey, suggesting that aesthetics may be context-specific rather than a sector-wide barrier. Similarly, participants supported stronger policy intervention and incentives, but some cautioned that poorly designed mandates could encourage unsuitable installations on shaded or poorly oriented roofs. This indicates that policy support must be carefully designed to avoid promoting symbolic adoption without ensuring technical performance.

The contribution of this study lies in its stakeholder-informed and mixed-methods explanation of SPVS-PH adoption in New Zealand. While previous SPVS-PH research has largely emphasised modelling, simulation, lifecycle performance, and technical feasibility [19,20], this study identifies and ranks the behavioural, financial, technical, and policy factors that influence real-world adoption. It also contributes to the literature by showing that SPVS-PH adoption is not limited to technology readiness alone but is also shaped by the alignment of perceived usefulness, ease of implementation, financial viability, policy support, and socio-technical conditions. The study provides a more integrated explanation of why SPVS adoption in PHs remains limited despite its environmental and technical benefits.

6. Conclusion

This study explored SPVS-PH adoption in New Zealand by examining current adoption trends, identifying key drivers, barriers, and strategies, and prioritising the most significant factors influencing adoption. A sequential mixed-methods approach was adopted, beginning with document analysis, followed by 34 semi-structured interviews, and concluding with a structured survey completed by 96 participants. The study draws the following conclusions:

1. SPVS-PH adoption in New Zealand is gradually emerging, as shown by the increase in PH Plus and Premium certifications. However, uptake within PHs remains limited compared with the wider growth of SPVS installations in conventional housing.
2. The qualitative phase identified 13 drivers, 18 barriers, and 18 strategies influencing SPVS-PH adoption. The highest-ranked drivers were support for New Zealand's low-carbon transition (M = 4.57), declining SPVS cost (M = 4.55), and improved environmental performance (M = 4.39).
3. The most significant barriers were budget priorities (M = 4.09), low solar buy-back rates (M = 3.87), and lack of financial incentives (M = 3.78). These findings indicate that SPVS-PH adoption is constrained more by economic and policy conditions than by technical feasibility alone.
4. The highest-ranked strategies were optimised SPVS design and installation (M = 4.54), battery integration (M = 4.53), and government incentives (M = 4.49). These strategies highlight the importance of combining technical design solutions with supportive policy and financial mechanisms.
5. Policy incentives and integrated design exhibit strong alignment between qualitative and quantitative measures. Both interview and survey findings aligned closely on ST1 (government incentives), ST4 (policy support), ST13 (integrated design), and ST16 (optimised design), receiving top quantitative ratings (means = 4.39–4.54).
6. Environmental sustainability is a cross-cutting theme. It was widely mentioned in interviews and received high mean scores (4.39–4.57), confirming strong agreement that the low-carbon transition and sustainability drive the adoption of SPVS-PH.
7. Economic and financial barriers dominate both qualitative and quantitative datasets. Participants consistently cited high capital costs and limited incentives as the highest quantitative barriers (means = 3.63–4.09).
8. The study contributes to sustainable residential development in New Zealand by providing a stakeholder-informed understanding of SPVS-PH adoption. It also supports Sustainable Development Goals 7 and 13 by identifying practical pathways to improve renewable energy integration in high-performance housing.
9. For policymakers, the findings highlight the need for targeted financial incentives and improved export arrangements. For architects, engineers, and energy consultants, the findings emphasise the importance of early-stage SPVS planning, system sizing, and battery-ready design.

6.1. Limitations of the study

This study has a few limitations; first, the findings are specific to the New Zealand residential building and energy policy context. Therefore, they should not be generalised directly to countries with different electricity markets, building regulations, or solar incentives. Secondly, the document analysis depended on available certification databases, institutional reports, and public policy documents, which may be affected by reporting delays or incomplete records.

6.2. Future research directions

Future research could build on this study by employing advanced modelling techniques, such as Partial Least Squares Structural Equation Modelling (PLS-SEM), to examine the interrelationships among the identified drivers, barriers, and strategies. This would provide deeper insight into how New Zealand-specific policy, market, and technical conditions influence SPVS-PH adoption.

CRediT authorship contribution statement

Franklin Chukwuebuka Nkado: Writing – original draft, Software, Methodology, Conceptualization. **Itohan Esther Aigwi:** Writing – review & editing, Supervision. **Dat Tien Doan:** Writing – review & editing, Supervision. **Ali GhaffarianHoseini:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Appendices

A.1. Appendix A1

Appendix A1
The interview participants' profile.

Participants	Role	Organisation type	Organisation size	Years of Experience
P1	Senior Electrical Engineer	Design Professionals	Large	14 Years
P2	Director, Electrical Consultancy Firm	Design Professional	Small	35 Years
P3	Director, Architectural Firm/Investor	Design Professional	Small	10 Years
P4	Director, Architectural Firm/ Lecturer	Design Professional/ Community/Others	Medium	27 Years
P5	Passive House & Energy Consultant/investor	Design Professional/ Others	Small	8 years
P6	Director, Solar Company	Design Professional	Large	10 years
P7	Business Development Manager	Policy Regulator	Large	13 years
P8	Eco-design Advisor	Design Professional	Large	21 years
P9	Eco-design Advisor	Design Professional	Large	8 years
P10	Innovation Manager	Policy Regulator	Large	7 years
P11	Director, Architectural Firm	Design Professional	Small	20 years
P12	Senior Registered Architect	Design Professional	Medium	22 years
P13	Sustainability Manager	Policy Regulator	Large	11 years
P14	Director, Architectural Firm	Design Professional	Small	13 Years
P15	Director, Architectural Firm	Design Professional	Small	9 years
P16	Director, Architectural Firm	Design Professional	Small	27 years
P17	Director, Architectural Firm	Design Professional	Small	31 years
P18	Registered Architect	Design Professional	Small	21 years
P19	Director, Architectural Firm	Design Professional	Small	13 years
P20	Sustainability Consultant	Community Members	Large	21 years
P21	Director, Energy Consultancy Firm	Community Members	Small	18 years
P22	Director, Electrical Engineering Firm	Industry	Medium	17 years
P23	Director, Architectural Firm	Design Professional	Medium	22 Years
P24	Director, Architectural Firm	Design Professional	Small	10 Years
P25	Director, Architectural Firm	Design Professional	Medium	23 Years
P26	Director, Carbon Consulting Firm	Community Member	Small	13 Years
P27	Director, Architectural Firm	Design Professional	Small	15 Years
P28	Director, Architectural Firm	Design Professional	Small	9 Years
P29	Senior Electrical Engineer	Design Professional	Large	20 Years
P30	Director, Architectural Firm	Design Professional	Small	10 Years
P31	Research Lead Advisor	Policy Regulator	Large	7 Years
P32	General Manager	Policy Regulator	Large	12 Years
P33	Energy Analyst	Policy Regulator	Large	10 Years
P34	Passive House Consultant	Design Professional	Small	5 Years

Appendix B. Appendix A2

Appendix A2
Themes from interview participants.

Themes/ Participants' ID	SPVS-PH Drivers					Barriers to SPVS-PH					Strategies for SPVS-PH Integration in New Zealand		
Participants	SPVS-PH Design Synergy	Economic Benefits	Energy Autonomy & Resilience	Environmental Sustainability & Carbon Mitigation	Social Benefits	Economic & Market Barriers	Design & Technical Limitations	Technological & Knowledge Gaps	Policy & Market Limitations	Aesthetic & Cultural Preferences	Enabling Policy & Incentives	Integrated Design & Technical Solutions	Education, Capacity & Collaboration
P1		✓					✓	✓	✓		✓	✓	
P2	✓			✓		✓		✓			✓	✓	✓
P3	✓		✓	✓		✓	✓		✓			✓	
P4	✓	✓				✓	✓			✓	✓		
P5	✓	✓				✓	✓	✓	✓			✓	✓
P6		✓		✓				✓	✓				✓
P7			✓			✓				✓		✓	
P8				✓		✓		✓		✓	✓	✓	
P9			✓			✓		✓			✓	✓	
P10	✓	✓			✓	✓	✓	✓	✓			✓	
P11	✓		✓			✓							
P12						✓	✓	✓					
P13		✓		✓		✓					✓	✓	
P14		✓	✓			✓				✓	✓	✓	
P15	✓	✓	✓			✓					✓	✓	✓

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Appendix A2 (*continued*)

Themes/ Participants' ID	SPVS-PH Drivers					Barriers to SPVS-PH					Strategies for SPVS-PH Integration in New Zealand		
Participants	SPVS-PH Design Synergy	Economic Benefits	Energy Autonomy & Resilience	Environmental Sustainability & Carbon Mitigation	Social Benefits	Economic & Market Barriers	Design & Technical Limitations	Technological & Knowledge Gaps	Policy & Market Limitations	Aesthetic & Cultural Preferences	Enabling Policy & Incentives	Integrated Design & Technical Solutions	Education, Capacity & Collaboration
P16	✓					✓	✓			✓	✓	✓	✓
P17	✓	✓		✓		✓	✓			✓	✓	✓	✓
P18	✓	✓	✓			✓	✓				✓	✓	✓
P19	✓					✓							
P20			✓	✓		✓	✓		✓		✓	✓	✓
P21		✓	✓	✓				✓	✓			✓	
P22			✓			✓	✓			✓	✓	✓	
P23	✓		✓			✓						✓	✓
P24				✓	✓	✓	✓					✓	
P25	✓	✓	✓	✓		✓					✓	✓	✓
P26	✓		✓		✓	✓	✓	✓				✓	✓
P27	✓		✓			✓				✓	✓	✓	
P28		✓	✓		✓	✓			✓			✓	
P29		✓									✓		
P30		✓	✓			✓					✓	✓	
P31						✓	✓		✓		✓		
P32	✓	✓	✓			✓						✓	
P33	✓					✓	✓	✓			✓	✓	✓
P34				✓		✓	✓				✓	✓	

Appendix C. Appendix A3

Appendix A3
Drivers for SPVS adoption in PHs.

Drivers for SPVS in PHs	Code
The ability to install a smaller-sized SPVS due to PH efficiency is a strong driver for adoption.	DR1
The technical compatibility between SPVS and PH design simplifies decision-making and system integration.	DR2
The declining cost of SPVS makes adoption in PHs more financially feasible	DR3
Reducing electricity bills is a key motivation for integrating SPVS in PHs	DR4
SPVS-PH integration leads to enhanced long-term financial returns for homeowners	DR5
The presence of SPVS increases the market value or desirability of PHs	DR6
Integrating SPVS with PHs helps reduce dependence on the national grid	DR7
The potential for off-grid or backup power supply is a major driver for SPVS adoption in PHs.	DR8
Adding SPVS to a PH improves its ability to cope with seasonal or extreme weather conditions.	DR9
Adding SPVS to a PH improves its environmental performance (e.g., lower grid electricity use and emissions).	DR10
Integrating SPVS into PH contributes to New Zealand's transition to a lower-emissions, renewable electricity system.	DR11
Combining SPVS with PH buildings is an effective way to demonstrate a commitment to sustainability.	DR12
The ability to export surplus solar electricity from PHs to the grid during peak demand motivates the adoption of SPVS in PHs.	DR13

Appendix D. Appendix A4

Appendix A4
Barriers to SPVS adoption in PHs.

Barriers	Code
Concerns about the visual impact of solar panels affect SPVS adoption in PHs.	BR1
Reluctance among some clients (e.g., homeowners/developers) to adopt SPVS reduces their uptake in PHs.	BR2
Trade-offs between reducing embodied carbon and minimising operational energy use present a challenge in SPVS-PH design decisions	BR3
The technical complexity of integrating SPVS into PHs (e.g., roof angle, space, wiring/conduit) often hinders SPVS adoption in PHs.	BR4
The seasonal mismatch between SPVS generation (summer-peaking) and PH heating demand (winter-peaking) is a concern.	BR5
In dense urban areas, limited roof area and shading make it challenging to install SPVS on PHs	BR6
Budget constraints lead clients (e.g., homeowners, developers) to prioritise other construction needs ahead of installing SPVS in PHs.	BR7
The high upfront cost of PH construction limits the adoption of SPVS	BR8
Extended SPVS payback periods in PHs due to their high energy efficiency discourage investment.	BR9
The lack of financial incentives reduces the appeal of adopting SPVS in PHs	BR10
Low buy-back rates for exported solar electricity reduce the appeal of installing SPVS in PHs	BR11
Short expected time living in a home (e.g., planning to move within ~5–7 years) reduces willingness to install SPVS in PHs because the payback is long-term.	BR12
The high cost of SPVS equipment and installation remains a barrier to SPVS-PH adoption.	BR13

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Appendix A4 (*continued*)

Barriers	Code
Limits on exporting solar electricity to the grid (e.g., distributor-imposed export caps) discourage investment in SPVS for PHs.	BR14
The perception that New Zealand's electricity grid is already mostly renewable reduces interest in installing SPVS in PHs.	BR15
The lack of load-shifting enablers (e.g., dynamic price signals such as time-of-use tariffs, or smart control systems) reduces the value realised from SPVS in PHs.	BR16
Concerns about the lifespan and reliability of solar PV equipment (panels, inverters, and batteries) reduce willingness to install SPVS in PHs	BR17
A traditional focus on the “fabric first” approach (prioritising envelope performance) often delays early consideration of SPVS in PH design.	BR18

Appendix E. Appendix A5

Appendix A5
Strategies to improve SPVS adoption in PHs.

Strategies to Improve SPVS-PH Adoption	Code
Government incentives (e.g., grants, rebates, low-interest loans) would increase the adoption of SPVS in PHs.	ST1
Requiring new buildings to include SPVS-ready features (e.g., suitable roof area, wiring/conduit, and switchboard capacity) is necessary to support the adoption of SPVS in PHs.	ST2
Aligning PH used in New Zealand with national renewable-energy policies and incentives is necessary to support the adoption of SPVS in PHs.	ST3
Targeted government subsidies or grants for integrating SPVS into PHs would increase adoption.	ST4
Time-of-use electricity pricing (cheaper off-peak rates) and advanced battery management (automated charge/discharge and load-shifting) would increase the value realised from SPVS in PHs (e.g., higher self-consumption and bill savings).	ST5
Flexible SPVS mounting solutions (e.g., ground-mounted arrays in open fields) should be promoted to address site infrastructure constraints (e.g., limited roof space or poor orientation) in PH projects.	ST6
Using whole-of-life carbon tools alongside PHPP (e.g., Phribbon, The Carbonator) helps quantify and optimise trade-offs between embodied and operational carbon when planning SPVS in PHs.	ST7
Communicating the long-term value of SPVS during the planning and design stages can help shift client budget priorities and encourage adoption in PH construction.	ST8
Framing SPVS, especially when paired with battery storage, as a resilience feature (e.g., outage coverage) and a long-term value proposition (e.g., bill savings, future-proofing), encourages inclusion in PH projects despite their low-energy demand.	ST9
Smart controls (e.g., automated load-shifting) and dynamic electricity pricing (e.g., time-of-use tariffs) increase the value realised from installing SPVS in PHs.	ST10
Using building-integrated photovoltaics (e.g., PV-integrated roofing) can improve aesthetics and reduce installation/roof-integration costs, increasing adoption of SPVS in PHs.	ST11
Utilising purpose-specific SPVS technologies such as DC-coupled SPVS for only hot water heating can reduce system costs, allow for smaller SPVS setups, and support wider adoption of SPVS in PHs.	ST12
Early energy budgeting and modelling (e.g., PHPP load + PV generation modelling) helps right-size SPVS and improves long-term energy and cost outcomes in PHs.	ST13
Grid-connected SPVS in PH that include battery storage enhance both home resilience (e.g., backup power during outages) and grid support (e.g., reducing peak load).	ST14
Grid-connected solar PV systems in Passive Houses without battery storage primarily support the grid but provide little benefit to household resilience.	ST15
Optimised SPVS design and professional installation are essential to maximise performance and encourage wider adoption in PH projects.	ST16
Utilising alternative storage, such as EV batteries and hot-water cylinders as thermal storage, can reduce reliance on dedicated home batteries and improve the cost-effectiveness of installing SPVS in PHs.	ST17
Training and updated practice guidance to complement a “fabric-first” approach are needed to support integrated SPVS design in Passive House projects.	ST18

Appendix F. Appendix A6

Appendix A6
Frequency Distribution of Interview Themes.

Main category	Theme	No. of participants coded	Percentage
Drivers	Economic benefits	17/34	50%
	SPVS-PH design synergy	16/34	47%
	Energy autonomy and resilience	17/34	50%
	Environmental sustainability & carbon mitigation	12/34	35%
	Social benefits	7/34	21%
Barriers	Economic and market barriers	30/34	88%
	Design and technical limitations	16/34	47%
	Technological and knowledge gaps	11/34	32%
	Policy and market limitations	9/34	27%
	Aesthetic and cultural preferences	9/34	27%
Strategies	Enabling policy and incentives	29/34	85%
	Integrated design and technical solutions	20/34	58%
	Education, capacity-building and collaboration	12/34	35%

Appendix G. Appendix A7

Appendix A7
Document Selection and Screening Process.

Selection stage	Description	Number of documents
Documents initially identified	Documents identified from PHINZ, iPHA, Sustainable Engineering Ltd., MBIE, Electricity Authority, EECA, and other relevant institutional sources	17
Duplicates removed	Repeated documents, overlapping database records, or duplicate policy sources removed	4
Documents screened	Documents screened for relevance to SPVS, PH certification, low-energy housing, or New Zealand residential energy policy	13
Documents excluded after screening	Documents excluded because they were not New Zealand-specific, not related to SPVS/PHs, outdated, promotional, or lacked usable data	2
Full documents assessed	Documents reviewed in full for relevance, credibility, recency, and usefulness to the research questions	11
Documents included in final analysis	Documents finally analysed and used to examine SPVS–PH adoption trends, certification patterns, and policy context	10

Appendix H. Appendix B1

Appendix B1
Demographic background for the survey participants.

Category	Respondents	
	Number	%
Background		
Engineering	34	35.4
Architecture	21	21.9
Policy regulators	16	16.7
Construction	14	14.6
Others	11	11.5
Years of experience		
3–5 years	19	19.8
6–10 years	16	16.7
11–15 years	16	16.7
More than 15 years	45	46.9
Organisation Size		
Small (1–10 employees)	45	46.9
Medium (11–50 employees)	27	28.1
Large (51+ employees)	24	25

Appendix I. Appendix B2

Appendix B2
One-sample t-test results for the SPVS-PH drivers.

Driver	Rank	Mean	SD	SE mean	*t*	df	Sig. (2-tailed)	Mean diff	Lower	Upper
DR1	11	3.76	1.112	0.114	6.700	95	<0.001	0.760	0.54	0.99
DR2	9	3.86	0.936	0.096	9.050	95	<0.001	0.865	0.67	1.05
DR3	2	4.55	0.709	0.072	21.452	95	<0.001	1.552	1.41	1.70
DR4	7	4.31	0.910	0.093	14.136	95	<0.001	1.313	1.13	1.50
DR5	5	4.36	0.809	0.083	16.518	95	<0.001	1.365	1.20	1.53
DR6	8	4.00	0.918	0.094	10.677	95	<0.001	1.000	0.81	1.19
DR7	6	4.32	0.888	0.091	14.589	95	<0.001	1.323	1.14	1.50
DR8	12	3.73	1.021	0.104	7.000	95	<0.001	0.729	0.52	0.94
DR9	13	3.58	1.139	0.116	5.016	95	<0.001	0.583	0.35	0.81
DR10	3	4.39	0.845	0.087	15.986	93	<0.001	1.394	1.22	1.57
DR11	1	4.57	0.677	0.069	22.778	95	<0.001	1.573	1.44	1.71
DR12	4	4.36	0.824	0.085	16.061	94	<0.001	1.358	1.19	1.53
DR13	10	3.80	0.991	0.101	7.933	95	<0.001	0.802	0.60	1.00

Appendix J. Appendix B3

Appendix B3
One-sample *t*-test results for the SPVS-PH barriers.

Barrier	Rank	Mean	SD	SE mean	*t*	df	Sig. (2-tailed)	Mean diff	Lower	Upper
BR1	18	2.40	1.105	0.115	−5.256	92	<0.001	−0.602	−0.83	−0.37
BR2	11	3.20	1.099	0.114	1.793	92	0.076	0.204	−0.02	0.43
BR3	12	3.21	1.076	0.111	1.917	93	0.058	0.213	−0.01	0.43
BR4	17	2.65	1.095	0.113	−3.110	93	0.002	−0.351	−0.58	−0.13
BR5	13	3.10	1.108	0.114	0.838	93	0.404	0.096	−0.13	0.32
BR6	14	3.12	1.125	0.116	1.008	93	0.316	0.117	−0.11	0.35
BR7	1	4.09	0.947	0.098	11.115	93	<0.001	1.085	0.89	1.28
BR8	4	3.63	1.111	0.115	5.506	92	<0.001	0.634	0.41	0.86
BR9	10	3.19	1.110	0.114	1.673	93	0.098	0.191	−0.04	0.42
BR10	2	3.78	1.069	0.110	7.042	93	<0.001	0.777	0.56	1.00
BR11	3	3.87	1.039	0.107	8.137	93	<0.001	0.872	0.66	1.09
BR12	9	3.46	1.152	0.119	3.851	93	<0.001	0.457	0.22	0.69
BR13	5	3.57	1.266	0.131	4.401	93	<0.001	0.574	0.32	0.83
BR14	6	3.55	1.084	0.112	4.949	93	<0.001	0.553	0.33	0.78
BR15	15	3.03	1.195	0.123	0.259	93	0.796	0.032	−0.21	0.28
BR16	8	3.52	1.002	0.103	5.042	93	<0.001	0.521	0.32	0.73
BR17	16	3.00	1.182	0.122	0.000	93	1.000	0.000	−0.24	0.24
BR18	7	3.55	1.103	0.114	4.861	93	<0.001	0.553	0.33	0.78

Appendix K. Appendix B4

Appendix B5
One-sample t-test results for the SPVS-PH strategies.

Strategies	Rank	Mean	SD	SE mean	*t*	df	Sig. (2-tailed)	Mean diff	Lower	Upper
ST1	3	4.49	0.746	0.077	19.312	92	<0.001	1.495	1.34	1.65
ST2	13	3.82	1.122	0.116	7.022	92	<0.001	0.817	0.59	1.05
ST3	12	3.94	0.965	0.100	9.352	92	<0.001	0.935	0.74	1.13
ST4	5	4.39	0.834	0.087	16.030	92	<0.001	1.387	1.22	1.56
ST5	9	4.22	0.883	0.092	13.273	92	<0.001	1.215	1.03	1.40
ST6	15	3.61	1.011	0.105	5.845	92	<0.001	0.613	0.40	0.82
ST7	14	3.84	0.816	0.085	9.841	91	<0.001	0.837	0.67	1.01
ST8	8	4.27	0.768	0.080	15.930	92	<0.001	1.269	1.11	1.43
ST9	10	4.20	0.904	0.094	12.853	92	<0.001	1.204	102	1.39
ST10	6	4.31	0.834	0.086	15.173	92	<0.001	1.312	1.14	1.48
ST11	17	3.52	1.017	0.105	4.892	92	<0.001	0.516	0.31	0.73
ST12	18	3.41	1.135	0.118	3.472	92	<0.001	0.409	0.17	0.64
ST13	4	4.39	0.710	0.074	18.787	91	<0.001	1.391	1.24	1.54
ST14	2	4.53	0.718	0.075	20.476	91	<0.001	1.533	1.38	1.68
ST15	16	3.58	1.242	0.130	4.447	91	<0.001	0.576	0.32	0.83
ST16	1	4.54	0.686	0.072	21.580	91	<0.001	1.543	1.40	1.69
ST17	7	4.34	0.816	0.085	15.720	91	<0.001	1.337	1.17	1.51
ST18	11	4.15	0.811	0.085	13.625	91	<0.001	1.152	0.98	1.32

Data availability

No data was used for the research described in the article.

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