

University of Wales Trinity Saint David
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Part 1 Critical Foundations for the Literature Review

The critical literature review for a Doctor of Business Administration is expected to establish an academic influence in the research area by evaluating the strengths and limitations of previous studies and justifying the need for a new study. Therefore, a critical literature review is not a summary of prior publications but an argument about what is known in the field, how that knowledge has been developed, where the existing literature remains limited in scope and why future research is necessary. The critical literature review is a structured research process that helps clarify the research problem and identify the areas that still require further analysis (Randolph, 2009). Given that clarifying the research problem also involves defining its scope, the present study focuses on UK-based wave energy start-ups rather than the wider marine energy sector.

For the present study, which is titled “**Comprehending the Bankability Nuances of Start-Up Businesses: The Case of UK Wave Energy**”, the critical function of the literature review is especially important because the research area of this study is fragmented across related literature rather than being consolidated and unified as a part of a single literature: The existing literature on marine renewable investment examines investor priorities, motivations, and decision criteria that determine whether investors view marine renewable ventures as credible and investable (Leete, Xu and Wheeler, 2013; Polzin et al., 2019). Innovation systems research identifies policy, institutional, and capability-related deficiencies that limit investment mobilisation, innovation and commercialisation. (Winskel et al., 2006; Hannon, Diemen and Skea, 2017; Corsatea, 2014). Techno-economic studies investigate cost parameters, technological reliability, and market readiness thresholds for marine energy technologies that are cost-effective, reliable, and mature enough for commercial deployment (Allan et al., 2011; Gray et al., 2017; Stegman et al., 2017). The governance literature analyses regulatory frameworks, approval processes and regulatory obligations that shape the conditions for project development (Wright, 2016; Greaves et al., 2016; Mackie and Velenturf, 2021). Yet these different lines of research do not automatically form a unified framework for a coherent understanding of bankability at the start-up business level. A DBA-level critical literature review must therefore do two things at once: at first, it must show a comprehensive understanding of the wider research area and then narrow it into a defensible research problem centred on bankability in UK wave energy startups.

Understanding the Critical Literature Review

Evaluation and theory-informed analysis are prioritised in a critical literature review over mere reporting. Contrary to merely listing research sources, a doctoral literature review should critically integrate existing findings in order to clarify the research problem (Randolph, 2009). This is especially crucial in DBA research, where originality may be based on critical analysis,

systematic synthesis, and practice-oriented problem identification, in addition to primary data collection.

The doctoral critical literature review can be summarised in five interrelated objectives.

- to define the research area and its parameters
- to critically evaluate and identify the primary concepts and theoretical perspectives
- to compare empirical findings and techniques across the literature
- to identify the existing literature's ambiguity, blind spots, and unresolved gaps
- to establish the rationale for the study's problem statement, research questions, and contribution to knowledge (Boote and Beile, 2005; Randolph, 2009)

For this study, the review must therefore do more than state that financing in wave energy is difficult. It must show why existing literature does not yet adequately explain the nuances of bankability for start-up businesses in the UK wave energy sector. That requires engagement not only with the wave energy literature but also with work on renewable energy finance, investor behaviour, innovation systems, technology commercialisation, and de-risking.

Critical versus Descriptive Review

At the doctoral level, the difference between descriptive and critical review is more than a matter of style. A descriptive review primarily summarises the existing literature, whereas a critical review evaluates the published research by explaining where findings or analyses conflict, and what remains unresolved. This difference between descriptive and critical review shapes the intellectual purpose of the literature review and its capacity to support a clearly defined research problem. Table 1 summarises the main review types and their relevance to the present study.

Table 1. Review types and their relevance to the present study

Review type	Key characteristic	Relevance to the present study
Descriptive review	Lists authors, topics, and findings	Useful for orientation but weak for building a DBA research gap
Critical review	Compares, evaluates, and synthesises studies	Better suited to identifying gaps in the conceptualisation of bankability
Systematic review	Uses clearly defined, transparent, and repeatable review procedures	Useful for transparency and a traceable review process
Critical review with systematic logic	Combines transparent search procedures with critical interpretation	Best fit for the present study

Source: Author's own synthesis based on Randolph (2009), Templier and Paré (2015), Liberati et al. (2009), Page et al. (2021), and Ketchen and Craighead (2023)

For this research topic, a descriptive review would state that wave energy is promising but underfunded, with inconsistent policy support and weak investor confidence. However, this statement would not be enough for a doctoral-level work. In comparison, a critical review would ask a more analytically focused set of questions, such as the sources of the problems, which stem mainly from technical immaturity, unstable future revenue, fragmented innovation support, or weak investor confidence and whether these factors operate independently or reinforce one another, the reason for weak investor confidence, even though there is a substantial public support. These kinds of questions transform the literature review from a descriptive summary into a critical analysis.

Structure of a DBA-level Critical Review

A well-developed critical literature review usually develops from comprehensive coverage to a conceptual focus. It introduces a broad research field, then narrows to the key concepts and debates, afterwards it evaluates the empirical literature, and finally identifies the specific gap that justifies the study. Poor reviews are frequently inadequate because they are too broad and poorly organised (Randolph, 2009). Therefore, a structured process is recommended that links review objectives, evidence collection, evaluation, and synthesis (Templier and Paré, 2015).

Table 2. Review stages and their relevance to the present study

Stage	Function in the review	Relevance to the present research
Wider field	Establish renewable energy finance and emerging technology commercialization	Shows that financeability depends on risk, return, and institutional context
Sector field	Narrow to marine and wave energy	Shows why ocean energy differs from mature renewables
Focal concept	Define bankability and related concepts	Distinguishes bankability from a simple lack of available finance
Critical synthesis	Compare investor, policy, innovation, and governance literatures	Shows that current explanations are weakly integrated
Gap statement	Identify what remains unresolved	Justifies the DBA focus on UK wave energy startups

Source: Author's own synthesis based on Randolph (2009) and Templier and Paré (2015)

For the present study, a thematic structure is more appropriate than a chronological one. This is because the relevant literature is spread across several related but distinct literatures rather than located within a single disciplinary area. Organising the chapter thematically, therefore, provides a clearer basis for synthesising the factors that shape the bankability of UK-based wave energy start-ups.

Research Approach for the Critical Review

Rather than a narrowly defined meta-analysis, this research uses transparency as a guide by clearly defined search methods, transparent source selection and clear reporting. Therefore, the literature review integrates critical interpretation with structured, transparent source identification and selection.

Search strategy

For this study's literature review, Google Scholar was used with specific keyword combinations related to bankability, wave energy, marine renewables, start-ups, investment, finance, commercialisation, the United Kingdom, and Scotland. The search process was implemented as thematic blocks to represent the financial, commercialisation and regulatory dimensions of the sector rather than as a single set of search terms. The main search blocks and illustrative search terms used in Google Scholar are summarised in Table 3.

Table 3. Search blocks and example search terms used in Google Scholar

Search block	Example search terms
Bankability and finance	bankability; financeability; investor confidence; investment barriers; venture finance; project finance
Sector, technology and geography	wave energy; marine energy; ocean energy; UK; United Kingdom; Scotland
Commercialisation and new venture development	start-up; early-stage firm; commercialisation; scaling; demonstration; wave energy developers
Policy, regulation and enabling conditions	policy support; risk; uncertainty; regulation; consenting; revenue support; infrastructure

Source: Author's own synthesis of search strategy blocks for the present study, based on Randolph (2009), Templier and Paré (2015), Liberati et al. (2009), and Page et al. (2021).

Boolean operators are utilised in combination with these terms to generate more specific search results and to establish a credible, controlled evidence base. For instance, a review might include combinations such as wave energy AND bankability, marine energy AND investor confidence AND UK, or wave energy AND policy support AND commercialisation.

Inclusion and exclusion criteria

Inclusion and exclusion criteria enhance transparency and prevent biased selection; thereby, establishing clear eligibility criteria enables readers to evaluate their validity and scope (Liberati et al., 2009). In this study, the criteria used are directly linked to the research problem.

Table 4. Inclusion and exclusion criteria for the present review

Inclusion criteria	Exclusion criteria
Peer reviewed journal articles and major scholarly reports	Purely promotional industry material with no analytical value
Studies on wave energy, marine energy, renewable finance, bankability, investor decision making, or commercialization	Studies limited to engineering design with no relevance to financeability or commercialization
UK focused studies plus closely relevant international work used for conceptual comparison	Studies with no relevance to wave energy, startup finance, or bankability conditions
Studies that address technical, commercial, policy, institutional, or regulatory dimensions of financeability	Sources that duplicate already included evidence without adding analytical value
Foundational older papers plus recent papers showing current interpretation of the field	Sources lacking sufficient methodological or conceptual clarity

Source: Author's own synthesis of inclusion and exclusion criteria for the present review, based on Randolph (2009), Templier and Paré (2015), Liberati et al. (2009) and Page et al. (2021).

These criteria are particularly critical in the present topic due to the irregular distribution of the literature. Several studies concentrate on policy development, stakeholder perspectives, or are solely centred on commercialisation. To include all bankability topics, a critical review must contain sufficiently diverse material while excluding publications that do not contribute to understanding access to finance.

Critical thinking in the analysis of literature

The task of a DBA-level literature review should analyse relationships between concepts, methods, findings, and assumptions across the field. Critical reading identifies the strengths and weaknesses of individual studies, but it also examines how studies relate to each other

and where their arguments and findings align or differ, and as a result, critical reading reveals the current knowledge of the field (Randolph, 2009; Ketchen and Craighead, 2023).

Theory, debates, and contradictions

Table 5. Key Debates and Tensions in the Literature for the present review

Tension	Key evidence	What it shows	Why it matters
Technological promise vs commercial confidence	Jin and Greaves (2021): strong UK wave potential, but no mature commercial deployment.	Technical promise does not equal bankability.	Investors need commercial proof, not just technical potential.
Public support vs private investment	Hannon, van Diemen and Skea (2017): long-term support did not create a viable sector because it was fragmented and over-optimistic.	Public funding can coexist with weak private confidence.	Support must be better designed to attract private capital.
Investor logic vs sector conditions	Leete, Xu and Wheeler (2013), Polzin et al. (2019), and Bucher et al. (2016): investors value risk reduction, revenue certainty, and credible maturity signals.	Bankability is shaped by risk, returns, policy, and readiness.	Wave ventures may struggle because sector conditions do not match investor expectations.

Source: Author's synthesis based on the reviewed literature.

These tensions suggest that bankability in UK wave energy is not determined by the interaction of technological maturity, policy design, revenue visibility, and investor confidence. The literature highlights a broader misalignment between sector conditions and the conditions under which private finance is committed. This supports the need for a more integrated approach to understanding startup bankability in the sector.

Part 1 Conclusion

A doctoral critical literature review is most effectively seen as an argument about what is currently known and the need for further research. Its purpose is to justify the study. Its content should combine field mapping, conceptual analysis, empirical synthesis, and gap identification. Its format should be thematic and cumulative, moving from a broad field to a focused research problem. For the present study, the review should not ask only whether wave energy is promising. It should ask under what conditions UK wave energy startups become bankable, for whom, and why those conditions remain difficult to achieve. That is the kind of narrowing and sharpening that turns a broad topic into a doctoral research problem.

PART 2 ANNOTATED BIBLIOGRAPHY

This annotated bibliography is thematically designed because the literature relevant to the present study is divided across multiple fields, such as finance, innovation and commercialisation. Furthermore, the studies were published at different time periods; therefore, this annotated bibliography combines recent journal articles with older foundational studies that are essential for the analysis (Winskel et al., 2006; Allan et al., 2011; Hannon, Diemen and Skea, 2017; Jin and Greaves, 2021; Wiegele and Jones, 2024; van der Schans, Owen and Hussain, 2025).

The aim of this annotated bibliography is not to list everything written on wave energy but to organise the most useful sources in order to explain not only why UK wave energy startups continue to struggle to attract finance but also to examine where the literature is strongest, limited and divided.

Table 6. Theme Map

Theme No.	Theme	Key Issue	Significance	Sources
Theme 1	Bankability, investor confidence, and startup finance	How capital providers judge emerging ventures	Gives the direct lens for the study	Leete, Xu and Wheeler, 2013; Bucher et al., 2016; Jeffrey et al., 2015; Wiegele and Jones, 2024
Theme 2	Policy support, revenue certainty, and market formation	How support design affects risk and returns	Explains why financing depends on policy credibility	Allan et al., 2011; Lockwood, 2016; Polzin et al., 2019

Theme 3	Innovation systems and ecosystem coordination	How institutions, networks, and learning shape commercialization	Shows that bankability is not only a firm level issue	Hannon, Diemen and Skea, 2017; Winskel et al., 2006; Corsatea, 2014
Theme 4	Techno economic readiness and commercialization pathways	How cost, reliability, readiness, and deployment logic interact	Explains why technology promise does not automatically become financeability	Guo and Ringwood, 2021; Weber, 2012; Weber, Costello and Ringwood, 2013; Weber et al., 2017; Ruiz-Minguella et al., 2022
Theme 5	Risk, due diligence, and staged investment	How uncertainty is assessed and managed	Connects bankability to actual investment judgment	Andres et al., 2017; Hutcheson, Andres and Jeffrey, 2016; Wilson, Rowley and Watson, 2011
Theme 6	Governance, consenting, and non-technical barriers	How regulation, legitimacy, and infrastructure affect financeability	Captures hidden costs and delays	Wright, 2016; Greaves et al., 2016; Mackie and Velenturf, 2021

Source: Author's synthesis based on the reviewed literature.

Theme 1 Synthesis: “Bankability, investor confidence, and startup finance”

Theme 1 shows that the financial challenge in wave and marine energy cannot be reduced to simply a shortage of capital; it should be viewed as a matter of bankability and venture credibility (see Table A1 in Appendix A and Table G1 in Appendix G). Although the literature shows that access to finance is closely associated with investor confidence and perceptions of credibility, it is less effective in explaining the extent to which these financing conditions operate at the start-up level. When the literature explains the reasons why the new ventures become financeable or unfinanceable in practice, this will make an analytically strong literature because now it only identifies the barriers.

The literature suggests that access to finance depends not only on whether wave energy technologies demonstrate potential, but also on the credible evidence of technical reliability,

revenue potential, and reduced uncertainty at different stages of development (Leete, Xu and Wheeler, 2013; Bucher et al., 2016; Jeffrey et al., 2015). This means that the claim that wave energy is underfunded is a simplistic view. At the same time, the existing literature usually presents “credibility” and “confidence” without adequate analytical explanation; moreover, it does not systematically specify which forms of evidence are considered credible by different categories of financiers at different stages of the development pathway. Although it is possible to achieve public support in the early stage, the literature indicates that the main bottleneck emerges in the development pathway, where the new venture needs support to attract broader commercial investment from the market (Jeffrey et al., 2015; Bucher and Bryden, 2016; Wiegele and Jones, 2024). The literature clearly identifies this bottleneck as a structural gap, but it does not explain well enough what exactly causes it.

A notable strength of Theme 1 is its focus on the credibility of policy because the literature shows that policy is important for finance not only by improving expected returns, but also by reducing perceptions of risk and increasing confidence in future market conditions (Dinica, 2006; Bürer and Wüstenhagen, 2009; Polzin et al., 2019). This statement is important for the focus of the present study because the wave energy sector's commercialisation relies on public support and pre-commercial testing opportunities. However, there is a lack of understanding of the effects of policy on different stages of development. Moreover, the cleantech finance studies indicate the inadequate alignment of traditional finance models with sectors like wave energy that need long-term capital-intensive innovation (Gaddy et al., 2017; Owen et al., 2020; van der Schans, Owen, and Hussain, 2025).

Theme 2 Synthesis: “Policy support, revenue certainty, and market formation”

The literature reviewed in Theme 2 clearly presents the importance of policy measures; it does not explain the effects on bankability across development stages. (see Table B1 in Appendix B and Table H1 in Appendix H). In addition, it doesn't provide information on whether the UK policy framework addresses the financeability of wave energy ventures. Another pattern across Theme 2 is that the structure of revenue support has an important role in shaping viability. The differentiated Renewables Obligation Certificate (ROC) banding is vital for wave and tidal technologies because they are significantly more expensive than mature renewables (Allan et al., 2011; Allan, McGregor and Swales, 2009). This is a valuable insight because generic support schemes don't create fair competitive conditions for marine energy.

A key critical insight from Theme 2 is that policy credibility is crucial for support levels. Investors are sensitive to support levels and risk allocation through the structure of the policy (Mitchell, Bauknecht and Connor, 2006; Kitzing and Weber, 2014; Polzin et al., 2019). In the case of the UK, reforms often generate new uncertainty instead of improvement, as the risk shifts back to developers and investors rather than reducing it, for example, the move from ROCs to

Contract for Difference (CfDs) and the operation of the Levy Control Framework (Bunn and Yusupov, 2015; Lockwood, 2016; Kozlov, 2014).

The literature also highlights a persistent misalignment between policy goals and the sector's commercial maturity. UK policy treats the wave energy and marine energy sectors as strategically important, but support mechanisms are not always aligned with the level of commercial and technological maturity (Jeffrey and Winskel, 2009; Watson and Fulcher, 2010; Willis et al., 2010). Similarly, other studies highlight that public support is vital, but they do not demonstrate that it was organised in the right order and at the right stages to generate long-term market development (Jeffrey, Sedgwick and Gerrard, 2014; Jeffrey, Jay and Winskel, 2013).

Overall, Theme 2 highlights that policy is a direct component of bankability rather than a background condition. Its strength is that revenue certainty and risk reduction are shaped by the support design; however, its weakness is that the literature is more effective at showing the importance of policy than explaining the reason why repeated policy interventions fail to create a stable bankability pathway for wave energy start-up businesses.

Theme 3 Synthesis: “Innovation systems and ecosystem coordination”

The strongest contribution of the literature reviewed in Theme 3 shows that wave energy bankability is shaped by the broad innovation system, so it is not sufficient to explain it at the firm level alone (see Table C1 in Appendix C and Table I1 in Appendix I). This theme shows that financial difficulty is not an internal problem of weak ventures or immature devices; bankability is affected by institutions, policy coherence, knowledge transfer and market development dynamics. However, while this perspective is valuable, the literature describes ecosystem weaknesses in broad terms and does not explain their effects on start-up financing difficulties.

One of the most important studies on this theme argues that the UK wave support did not deliver the intended outcomes, not due to technological difficulties or high costs, but because the support system encouraged commercialisation while learning too little; more specifically, the innovation system was poorly coordinated (Hannon, van Diemen and Skea, 2017). The literature is strong due to explaining the problem as a deep structural weakness in the innovation system not only in terms of cost. However, the argument is primarily based on the wave energy experience in the UK during the 2000s and early 2010s, so it is unclear how far those same weaknesses still shape the current conditions of the sector.

A second important pattern from Theme 3 is that marine energy development depends on financial capital, collaborative learning, social capital and institutional coordination (Winskel et al., 2006; Winskel, 2007) and more importantly if the emerging technologies are progressing through the commercialisation valley of death, coordination between institutions and

developers is critical (Corsatea, 2014). These studies show that ventures do not become bankable in isolation but within the systems that can either help or hold back the development of knowledge and credibility. Although the literature highlights the conditions of the ecosystem, it is less clear which forms of coordination are most important for financeability and across different stages of venture development. The technological innovation systems literature helps explain how sector development can be slowed or blocked by weak market formation, knowledge transfer, and resource mobilisation (Gallagher et al., 2012; Negro, 2007; Suurs and Hekkert, 2009; Dewald and Truffer, 2017). Although the study is generic, it can help to explain why the wave energy sector has difficulty converting technical promise into commercial progress.

Overall, Theme 3 argues that bankability depends not only on firm-level factors but also on the wider ecosystem. The main limitation of the literature is more effective at identifying innovation system problems than at demonstrating how those problems affect financing decisions, start-up development, and investor behaviour.

Theme 4 Synthesis: “Techno-economic readiness and commercialisation pathways”

The literature reviewed in Theme 4 shows that techno-economic readiness is crucial for bankability, as investors are not convinced by promises alone, but they require credible techno-economic evidence (see Table D1 in Appendix D and Table J1 in Appendix J). This theme is important for the wave energy sector because, without an optimistic outlook on the sector's potential, it raises the question of whether technical progress is sufficient to enable realistic pathways to commercialisation. At the same time, the literature shows that the techno-economic evidence needed to maintain investor confidence is not adequately developed by the wave energy sector. In this respect, the issue is not about high costs, so that the future performance, reliability and cost reduction remain uncertain.

The literature shows that commercial deployment is not simply the consequence of technological progress but also a precondition for further progress. Early finance is important because repeatedly using and testing the technology in real-world conditions provides operational evidence, reduces costs, and builds technical maturity, and generating the evidence will improve the financeability in the later stages (MacGillivray, Jeffrey and Wallace, 2015; MacGillivray et al., 2014). But this creates a circular problem because investors need evidence before funding, yet deployment is only possible when financing is available. And the literature recognises this circularity problem as an accepted condition rather than analysing how to overcome it in practice.

A second important finding is that wave energy technologies remain commercially underdeveloped and insufficiently consolidated because there is no clear route to competitiveness like that of other energy sources, and due to high costs (Guo and Ringwood,

2021; Astariz and Iglesias, 2015, 2016; Stegman et al., 2017). This literature is important because it challenges the assumption that the financial challenge of the wave energy sector is solely due to inadequate policy support or investor risk aversion. However, the literature focuses on the sector as a whole and lacks an explanation of how these weaknesses shape financing decisions for specific ventures.

The literature of Theme 4 questions how techno-economic readiness should be measured. Technology Readiness Levels alone are insufficient, so technology performance must also be evaluated alongside readiness (Weber, 2012; Weber, Costello, and Ringwood, 2013; Weber et al., 2017). It is the most useful contribution of this theme because it clarifies evidence quality and signalling. Similarly, inconsistent approaches to economic evaluation limit comparability, and this makes investment decisions more difficult (Têtu and Fernández Chozas, 2021). However, much of the literature is shaped by analytical frameworks rather than by direct evidence on investor behaviour.

Overall, Theme 4 shows that credible techno-economic evidence influences bankability. Its strength is to explain why progress is slow, and its weakness is that the literature cannot clearly connect technical problems to the real financing challenges faced by start-ups.

Theme 5 Synthesis: “Risk, due diligence, and staged investment”

The literature reviewed in Theme 5 shows that the financeability of wave and marine energy depends not simply on cost expectations, but also on how uncertainty is managed by investors and developers (see Table E1 in Appendix E and Table K1 in Appendix K). This theme moves beyond Levelized Cost of Energy (LCOE)-based assessments by showing that investment decisions are shaped by a wide range of risks such as technical, operational and institutional. However, the literature demonstrates the importance of uncertainty rather than explaining the effects of risk on the funding decisions of start-up ventures in practice. Much of the literature focuses on models and technology-level case studies rather than on how firms and investors actually make financing decisions in practice.

A clear pattern is that the literature moves decisively beyond cost-only logic. A consistent finding in the literature is that cost alone is insufficient to judge the attractiveness of ocean energy. Studies show that LCOE alone does not capture the overall bankability profile of the venture because of technical, commercial, or policy high risks; low-cost options may still be unattractive to investors (Andres et al., 2017; Hutcheson, Andres, and Jeffrey, 2016). Even though cost metrics do not capture the full picture, they are often taken as signs of commercial readiness. However, commercial readiness cannot be evaluated by considering only the device; it also requires attention to logistics and developer capabilities, as well as wider system factors (Wilson, Rowley and Watson, 2011). These studies are valuable because they align

closely with a broader understanding of bankability, but they are stronger as analytical frameworks than as direct evidence of investor behaviour in practice.

A second important pattern in the literature is the criticality of uncertainty analysis. Marine energy projects may appear more or less attractive depending on the assumptions about revenue and financial performance used in the financial evaluation (Guanche et al., 2014; Shah et al., 2017; Shah 2018). This is important because the problem is not only the technology itself, but also how uncertainty is analysed. So, a project may appear less financeable because of weak risk estimation, not just because of weak technical performance. However, the literature sufficiently analyses projects technically but is weaker at showing how different types of funders and investors actually interpret uncertainty when making financing decisions. The literature also highlights the importance of timing and staged investment, suggesting that delaying investment may be economically rational under conditions of persistent uncertainty (MacDougall, 2017; MacDougall, 2018). This is a valuable insight because these studies help explain why finance can remain blocked even when technologies appear strategically attractive; however, because they are based mainly on tidal energy, their relevance to wave energy should be treated with caution.

Overall, the Theme 5 literature offers valuable insights because it reframes financeability as shaped by risk visibility, risk allocation, and timing rather than by cost alone. Its main limitation, however, is that the literature remains fragmented across modelling, appraisal, and analogy-based studies, and it also offers only limited direct evidence of how wave energy investors actually make staged financing decisions.

Theme 6 Synthesis: “Governance, consenting, and non-technical barriers”

Non-technical barriers are part of the finance problem in wave energy; in fact, they are one of the factors that actively shape it (see Table F1 in Appendix F and Table L1 in Appendix L). The major strength of Theme 6 is that it determines that factors such as the wider regulatory and institutional environment can also affect whether the venture is seen as credible and investable by investors. The literature demonstrates that when the regulatory pathway is uncertain and slow, the projects and ventures may remain unattractive to investors.

A strong pattern in the literature is that regulatory complexity is a significant barrier, even regulatory uncertainty and licensing requirements may significantly delay development (Wright, 2016; Leary and Esteban, 2009; Neumann et al., 2006). This is highlighted by evidence that environmental impact assessment is not a simple procedural step but a documentary and administrative burden (Greaves et al., 2016; Harrington and Andina-Pendás, 2008). This is important because it suggests that bankability may be weakened by the uncertainty and costs generated by governance processes.

The literature also suggests that support infrastructure and learning through practice, such as test centres, the European Marine Energy Centre (EMEC) and Wave Hub, can reduce practical barriers for developers (Norris, 2009; Smith et al., 2009). However, such institutions may reduce operational inefficiencies, but they do not resolve deeper structural problems such as regulatory complexity and stakeholder conflict.

The literature highlights the importance of stakeholder and environmental credibility; moreover, it suggests that project credibility is shaped by social acceptance, ecological data, and local stakeholder expectations (Simas et al. 2012; West, Bailey and Whitehead 2019; Witt et al., 2012). However, this work focuses on individual cases, and it does not show in a broader and systematic way to deal with legitimacy-related problems that influence financing outcomes. Similarly, decommissioning obligations may create liabilities that are not apparent to investors in the short term; although the literature is effective to identify these decommissioning liabilities, it is limited in explaining how investors assess them (Mackie and Velenturf, 2021).

Overall, Theme 6 makes clear that non-technical barriers, such as governance and regulation, are part of the finance problem and are part of the mechanism through which wave ventures become harder to finance. However, the literature lists barriers rather than explaining systematically how they affect the bankability of start-up ventures.

Overall synthesis across themes

Across all literature, it is indicated that the bankability of UK wave energy start-up businesses is not a simple shortage of finance, but instead it is shaped by the interaction of different factors from wider ecosystem support, such as technical credibility, investor confidence, and policy credibility (McCoy and Schwartz, 2022; Romero, Sulima and Conibeer, 2017; Leete, Xu and Wheeler, 2013; Polzin et al., 2019; Guo and Ringwood, 2021). One of the strengths of literature is that it moves beyond narrow cost-based explanations. However, the literature is more limited in explaining how these factors produce bankability in practice. Although these factors, technical, commercial, policy, and ecosystem factors, are frequently identified together, there is a lack of a coherent framework that explains how ventures become financeable across different stages of development.

There is limited attention to the transition from public support to private capital, even though it is one of the most fragile points in the financing pathway. Studies in wave energy and adjacent cleantech sectors suggest that for private capital, grants, demonstration programmes, and supportive policy conditions won't make ventures sufficiently credible and investment readiness (Jeffrey et al., 2015; Wiegele and Jones, 2024; O'Reilly, Mac an Bhaird and Greene, 2024). Much of the existing research remains underfocused on the venture-level and investor-level processes through which bankability is assessed in practice; instead, it focuses on

sector-level conditions and policy design (Hannon, Diemen and Skea, 2017; Jin and Greaves, 2021; Cowling and Liu, 2021). Consequently, a clear gap remains between broad explanations of sector-level barriers and a well-specified explanation of how funding decisions are shaped in practice. The literature still does not clearly explain whether wave energy struggles to attract finance mainly because the technology is not mature enough or because existing finance systems are a poor fit for it. It also does not clearly explain whether bankability should be understood as a feature of the project, the firm, or the wider ecosystem.

PART 3

PRELIMINARY CRITICAL LITERATURE REVIEW FOR UK WAVE ENERGY BANKABILITY

3.1 Introduction

The literature on UK wave energy combines insights from multiple fields, such as renewable energy finance, clean technology commercialisation, innovation systems, infrastructure governance, and project risk. Within the UK context, wave energy continues to be presented as strategically important to the United Kingdom due to its resource base, possible contribution to decarbonisation, and relevance to regional industrial development (Jin and Greaves, 2021; Jeffrey, Jay and Winskel, 2013). Furthermore, the literature shows that wave energy has repeatedly struggled to convert technical promise and public support into long-term commercial development (Hannon, van Diemen and Skea, 2017; Guo and Ringwood, 2021; Wiegele and Jones, 2024). The central problem is therefore not simply whether wave energy has potential, but why ventures in this field remain difficult to finance.

This bankability problem is important for three reasons. First, the transition to low-carbon energy has increased pressure to identify technologies that can support net-zero ambitions while strengthening energy security. Second, the UK retains strong wave resources and continued policy interest, whereas commercial outcomes remain weak relative to earlier expectations (Jin and Greaves, 2021). Third, the renewable energy and transition finance literatures demonstrate that emerging technologies do not become financeable solely on the basis of technical potential; they also require credible institutional, policy, and market conditions that enable relevant capital providers to engage (Polzin et al., 2019; Geddes and Schmidt, 2020). This makes UK wave energy a useful case for examining how bankability is constructed, delayed, or undermined in the context of high-risk, long-horizon wave energy ventures.

The practical problem is evident in the persistent difficulty of moving from prototype development and public support to credible commercial finance. The academic problem is that the literature explains this financing difficulty in fragments. Investor studies emphasise risk, return, and policy credibility (Leete, Xu and Wheeler, 2013; Polzin et al., 2019). Innovation system studies emphasise weak learning, fragmented institutions, and poor coordination

(Winskel et al., 2006; Hannon, van Diemen and Skea, 2017). Techno-economic studies emphasise cost uncertainty, reliability problems, and lack of convergence (Guo and Ringwood, 2021; Gray et al., 2017; Topper et al., 2019). Governance studies emphasise consenting, compliance, and regulatory burdens (Wright, 2016; Greaves et al., 2016). Even though these related studies are individually valuable, they do not yet provide an integrated explanation of startup bankability in the UK wave energy.

The aim of this critical literature review is to develop a clearer explanation of why UK wave energy startups struggle to become financeable. More specifically, it seeks to synthesise the literature through the concept of bankability and identify the conditions, such as technical, commercial, policy, institutional, and regulatory conditions, that shape whether ventures can move from early support to credible commercial finance.

3.2 Conceptual framing

A central difficulty in this field is that bankability is not often clearly defined. In much of the marine energy literature, discussion appears in references to investor confidence, financing barriers, commercial readiness, risk reduction, or due diligence thresholds rather than a limited treatment of bankability itself (Leete, Xu and Wheeler, 2013; Bucher et al., 2016; Jeffrey et al., 2015). This creates an analytical problem because it becomes difficult to distinguish bankability from related concepts such as investment attractiveness, access to funding, or commercial viability.

An important starting point is provided by McCoy and Schwartz (2022), who argue that bankability should be treated as a context-dependent assessment shaped by stakeholder type, financing structure, project phase, asset characteristics, and institutional context. Similarly, Romero, Sulima and Conibeer (2017) suggest that new energy technologies become bankable only when financiers judge technology risk to be sufficiently manageable. In renewable finance research, Polzin et al. (2019) show that investors engage where policy and market conditions together improve expected return and lower perceived risk. As a whole, these studies suggest that bankability is not a static quality of a technology or venture.

For this study, bankability can therefore be defined as the degree to which a wave energy startup, its technology, and its route to market are judged financeable by relevant capital providers at a given stage of development. This definition highlights three important points. First, bankability is stage-sensitive because the criteria that matter at concept, prototype, demonstration, and pre-commercial stages are not identical (Nightingale et al., 2016; Murphy and Edwards, 2003). Second, bankability is relational, because the same venture may appear attractive to one capital provider and unacceptable to another. Third, bankability is ecosystem-bound because it depends not only on venture quality but also on policy credibility, support

infrastructure, institutional coordination, and regulatory conditions (Hannon, van Diemen and Skea, 2017; Winskel et al., 2006; Wright, 2016).

3.2.1 Theoretical background

This study draws on several interconnected theoretical perspectives. The bankability problem is the interaction of financial, technological, institutional, and regulatory factors, so that no single theory is sufficient on its own to study bankability. Therefore, the theoretical background for this study combines ideas from multiple dimensions, such as bankability research, renewable energy finance, innovation systems, commercialisation theory, and policy risk.

The first perspective is bankability as a relational and stage-sensitive construct. McCoy and Schwartz (2022) argue that bankability is not a fixed attribute, but a judgment shaped by actor type, financing structure, project phase, and institutional setting. Romero, Sulima and Conibeer (2017) support this by showing that bankability in new energy technologies depends on how financiers interpret and allocate technology risk. This perspective is important because it shifts the analysis away from the simplistic question of whether finance exists and towards the more precise question of under what conditions a venture is judged financeable.

The second perspective comes from investor logic and renewable energy finance. Polzin et al. (2019) show that private finance is mobilised when policy and market conditions improve expected return while reducing perceived risk. Nightingale et al. (2016) add that finance is not neutral because different types of financiers support different technologies, stages, and risk levels. Together, these studies help explain why access to finance in wave energy cannot be treated as a generic capital shortage.

The third perspective is provided by innovation systems theory, particularly technological innovation systems. Winskel et al. (2006) show that marine energy development is shaped by institutional context, policy structure, and the tension between financial capital and social capital. Gallagher et al. (2012) and Negro (2007) further suggest that emerging energy technologies depend on the interaction of system functions such as knowledge development, market formation, resource mobilisation, and legitimacy. This perspective is highly relevant because it shows that startup bankability is not determined by firm-level quality alone, but by the wider ecosystem in which the venture is embedded.

The fourth perspective comes from commercialisation and the valley-of-death theory. Murphy and Edwards (2003) identify a structurally fragile stage for emerging technologies during the transition from public to private funding. Jeffrey et al. (2015) reinforce this in marine energy by showing that weak proof and uncertain returns may block the path from demonstration to market acceptance. The significance of this perspective is that framing the financeability as a staged process rather than a one-off event.

The fifth perspective emphasises the influence of regulatory risk, market formation, and policy credibility on bankability. Mitchell, Bauknecht, and Connor (2006) and Kitzing and Weber (2014) have shown that policy instruments transform the risk that investors experience, thereby influencing their investment decisions. This reasoning is further developed by Wright (2016), who demonstrates that regulatory and governance burdens can significantly undermine confidence in projects. Together, these theories suggest that bankability is shaped not only by technical and commercial factors but also by the credibility of the policy and regulatory environment.

Taken together, these perspectives provide the foundation for analysing bankability in UK wave energy startups as a staged, relational, and ecosystem-bound condition.

3.2.2 Scope of the review

The focus of this review is not renewable energy finance in general, nor wave technology performance in isolation. It is specifically the problem of startup bankability in the UK wave energy. The unit of analysis is therefore the startup venture moving through a financing pathway, rather than the sector as a whole or a single utility-scale project. This matters because much of the existing literature is organised around technologies, projects, or policy instruments rather than startup ventures as such.

3.3 Thematic literature review

3.3.1 Bankability, investor confidence, and startup finance

The most direct literature indicates that the financing problem in wave and marine energy is better understood as a bankability issue than as a simple capital shortage. Leete, Xu and Wheeler (2013) show that investors in UK marine renewables are highly sensitive to revenue certainty, policy credibility, and risk reduction. Bucher et al. (2016) and Jeffrey et al. (2015) deepen this by showing that marine energy is trapped in a circular dependence between finance and proof: funding is needed to improve performance, yet credible evidence of performance is needed to attract funding. This is one of the strongest insights in the field because it explains why strategically supported technologies can remain commercially stalled. However, this literature is less convincing in showing exactly how confidence and credibility operate at the startup level. The importance of maturity signals is repeatedly asserted, but less often unpacked in terms of what counts as persuasive evidence for different funders at different stages. More recent adjacent cleantech finance work strengthens this critique by showing that conventional venture capital is often poorly aligned with long-horizon, capital-intensive energy innovation (Gaddy et al., 2017; Owen et al., 2020; O'Reilly, Mac an Bhaird and Greene, 2024). This suggests that wave energy finance problems may reflect not only

technology risk, but also a mismatch between available finance models and venture development pathways.

A key contradiction in this theme is whether the main problem lies in investor caution or in the design of the finance system itself. Some studies suggest that investors respond rationally to high uncertainty and weak maturity signals (Leete, Xu, and Wheeler, 2013; Bucher et al., 2016). Others suggest that existing funding structures are not designed for technologies that take long periods to generate commercially acceptable evidence (Gaddy et al., 2017; Geddes and Schmidt, 2020). The literature supports both views to some extent but has not yet integrated them into a single startup-focused explanation.

3.3.2 Policy support, revenue certainty, and market formation

The policy literature demonstrates that support mechanisms are significant because they affect revenue levels and the credibility of future revenue. Wave and tidal technologies were unable to compete with mature renewables under generic regulations, as shown by Allan et al. (2011) and Allan, McGregor, and Swales (2009). Consequently, specialised assistance was necessary. Mitchell, Bauknecht, and Connor (2006) and Kitzing and Weber (2014) further demonstrate that support instruments differ in their approaches to risk allocation, suggesting that policy design has a direct impact on investment behaviour.

However, the UK case indicates that policy support has frequently facilitated activity without establishing a sustainable path to bankability. New forms of uncertainty for emerging technologies were introduced by reforms such as the transition from ROCs to CfDs and the operation of the Levy Control Framework, as indicated by Bunn and Yusupov (2015), Lockwood (2016), and Kozlov (2014). The critical aspect of this situation is that policy may appear to be supportive, but it may not generate revenue credibility for early-stage ventures. The literature is therefore strong in its demonstration that policy is significant; however, it is less effective in clarifying the reason why a stable market formation pathway for wave energy startups has not yet been established through repeated intervention.

3.3.3 Innovation systems and ecosystem coordination

The innovation systems literature offers one of the strongest explanations for persistent financeability problems. Winskel et al. (2006) and Winskel (2007) show that marine energy depends not only on financial capital, but also on social capital, collaborative learning, and institutional alignment. This is important because it shifts analysis beyond the firm and shows that ventures do not become bankable in isolation.

The most influential study here is Hannon, van Diemen and Skea (2017), which argues that UK wave support failed because it pushed commercialisation too quickly while learning too little. Their diagnosis of fragmentation, unrealistic expectations, insufficient knowledge

retention, and poor scheduling is of great importance, as it further clarifies why public support did not translate into commercial credibility. This interpretation is further supported by conceptual technological innovation systems research, which demonstrates that market formation, knowledge diffusion, entrepreneurial experimentation, and resource mobilisation must interact positively in order for emerging sectors to advance (Gallagher et al., 2012; Negro, 2007). Nevertheless, the literature is more effective at identifying ecosystem weaknesses than at demonstrating the precise manner in which these system weaknesses result in financing outcomes for specific ventures.

3.3.4 Techno-economic readiness and commercialisation pathways

The techno-economic literature demonstrates that the credibility of technical and commercial evidence is a significant factor in the viability of financing. Wave energy is still constrained by high costs, weak convergence, operational uncertainty, and the absence of a clear path to competitiveness, as indicated by Guo and Ringwood (2021), Astariz and Iglesias (2015), O'Connor, Lewis and Dalton (2013), Grey et al. (2017), Topper et al. (2019), and Ruiz-Minguela et al. (2022). This is significant because it demonstrates that investor caution is not solely perception; there are genuine techno-economic reasons for hesitancy.

Simultaneously, this literature demonstrates a circular issue. Learning and cost reduction necessitate repeated deployment; however, this requires financing that is challenging to obtain without more robust evidence. Technology Readiness Levels alone are insufficient; performance and economic relevance must also be demonstrated, as shown by Weber (2012), Weber, Costello and Ringwood (2013), and Weber et al. (2017). A critical contradiction in this context is whether incremental deployment-led learning is sufficient or whether more radical innovation and alternative pathways are required to establish credible commercial progression.

3.3.5 Risk, due diligence, and staged investment

The risk and due diligence literature challenges narrow cost-based assessments of marine energy investment. Andres et al. (2017) and Hutcheson, Andres and Jeffrey (2016) show that attractiveness cannot be judged by LCOE alone because low-cost pathways may still be unattractive if associated risks are too high. Wilson, Rowley and Watson (2011) argue that due diligence should assess the whole system, including logistics, grid access, permits, and lifecycle factors.

This literature is valuable because it shows that financeability is a whole-system judgement. Guanche et al. (2014) and related uncertainty work show that assumptions around yield, cost, and return can materially alter investment conclusions. More broadly, this theme suggests that finance may stall not because investors are irrationally conservative, but because uncertainty

is layered, difficult to price, and often unresolved. The limitation is that much of this literature remains project-based and technical rather than directly focused on startup finance decisions.

3.3.6 Governance, consenting, and non-technical burdens

The non-technical barriers literature shows that governance, consenting, environmental monitoring, and decommissioning obligations are not peripheral to the finance problem; they are part of it. Wright (2016), Iskandarova and Simakova (2012), West, Bailey and Whitehead (2019), and related governance work show that regulatory complexity, stakeholder expectations, and permitting burdens create real uncertainty for marine energy development. This matters because ventures may appear less financeable due to delay, evidential burden, compliance cost, and long-tail liability rather than technology weakness alone.

The weakness of this theme is that it is better at cataloguing governance burdens than at linking them directly to startup bankability. The financial consequences are clear by implication, but less often analysed directly.

3.4 Synthesis of findings

Three major patterns emerge across the literature. First, the finance problem is clearly multi-dimensional. The literature no longer supports the view that capital shortage is the reason for the slow progress in wave energy. Instead, the evidence points to interacting weaknesses in technical feasibility, revenue confidence, ecosystem and stakeholder support, regulatory clarity, and compatibility with finance models (Leete, Xu and Wheeler, 2013; Hannon, van Diemen and Skea, 2017; Guo and Ringwood, 2021; Geddes and Schmidt, 2020).

Second, the transition from early-stage support to private commercial finance is the most fragile stage in the development pathway, and this pattern is identified across commercialisation and investor-focused studies (Bucher et al., 2016; Jeffrey et al., 2015; Wiegele and Jones, 2024; O'Reilly, Mac an Bhaird and Greene, 2024).

Third, the literature emphasises that the credibility of evidence is more important than the attractiveness of claims. Technical maturity, strategic positioning or policy ambition are not sufficient. The critical issue is whether ventures can generate credible, stage-appropriate evidence that investors recognise as indicative of commercial viability and investment readiness. (Weber, 2012; Weber, Costello and Ringwood, 2013; Weber et al., 2017).

3.5 Conceptual framework

Table 7 Conceptual framework for the bankability of UK wave energy startups

Condition	Core content	Role in bankability
Technical credibility	Reliability, performance proof, engineering robustness, demonstrable progress	Directly affects whether ventures appear commercially believable
Revenue credibility	Believable route to income, market access, support-backed cash-flow visibility	Shapes whether future returns appear financeable
Policy credibility	Stability, predictability, and appropriateness of support design	Moderates perceived risk and revenue confidence
Ecosystem credibility	Test infrastructure, intermediaries, learning, supply chain, institutional coordination	Mediates whether technical progress becomes trusted commercial evidence
Regulatory credibility	Consenting clarity, compliance burden, decommissioning obligations	Moderates cost, delay, and liability expectations
Staged finance fit	Match between venture stage and available capital type	Mediates whether credible ventures can actually access suitable finance

Source: Author's own synthesis based on McCoy and Schwartz (2022), Polzin et al. (2019), Hannon, van Diemen and Skea (2017), Winskel et al. (2006), Nightingale et al. (2016) and Wright (2016).

Table 7 shows that startup bankability in the UK wave energy industry depends on six interrelated conditions that shape venture progress.

3.6 Research gaps

Table 8. Gap matrix for the literature on UK wave energy startup bankability

Gap type	Established Insights in the Literature	Key Limitations	Relevance to the Study
Theoretical	Investor preference, innovation systems, policy risk, valley of death, transition finance	A joined theory of startup bankability in UK wave energy	The study needs a clearer explanatory framework rather than another list of barriers
Empirical	Sector-level barriers, investor views, policy history, techno-economic uncertainty	Firm-level and deal-level evidence on how financing decisions are made	Bankability is judged in practice at venture and transaction level
Contextual	UK wave policy history and marine energy ecosystem	Comparative evidence across UK regions, financing stages, and post-2021 market conditions	The field may overgeneralise from a narrow historical window
Methodological	Reviews, expert interviews, stakeholder studies, modelling	Longitudinal, mixed-method, and cross-level designs that connect policy, firm, and finance decisions	Existing methods often capture only one layer of the problem at a time

Source: Author's synthesis based on the reviewed literature.

3.6.1 Theoretical gaps

Bankability is assumed rather than clearly defined. Although studies address investor confidence, financial barriers, investment readiness thresholds, policy stability, and due diligence, the literature rarely analyses bankability as an analytical concept with well-specified dimensions (Leete, Xu and Wheeler, 2013; Bucher et al., 2016; Jeffrey et al., 2015).

A second weakness is the limited integration of startup finance theory and socio-technical transition theory. Cleantech and valley-of-death studies demonstrate that capital-intensive ventures requiring long development periods misalign with traditional venture capital models (Gaddy et al., 2017; Owen et al., 2020; O'Reilly, Mac an Bhaird and Greene, 2024; van der

Schans, Owen and Hussain, 2025), while transition research shows that niche technologies should align or reshape the expectations of established financial regimes (Geddes and Schmidt, 2020).

The third gap relates to the evidence. The literature indicates that investor confidence depends on both technological maturity and Technology Readiness Level (TRL), with the evidence of techno-economic performance (Weber, 2012; Weber, Costello and Ringwood, 2013; Weber et al., 2017). Even so, it remains unclear which kind of techno-economic evidence shapes bankability across different stages of development.

3.6.2 Empirical gaps

The most robust evidence is mainly concentrated at the sectoral level rather than venture-specific. Hannon, van Diemen and Skea (2017) highlight how poor support and early-scale-up weakened the UK wave energy development; Jin and Greaves (2021) review the sector's present condition and future potential; and Leete, Xu and Wheeler (2013) identify investor criteria. However, firm-level and investment-transaction evidence remains limited, and this important gap shows that startup bankability cannot be understood fully from sector-level patterns alone; it requires closer attention to how financing decisions are organised in practice.

3.6.3 Contextual gaps

The literature analyses the UK market extensively across numerous studies, but it tends to treat the UK as a single market with a homogeneous policy framework. More locally grounded analysis is needed to study the roles of regional institutions, infrastructure, and regulatory authorities and how they shape bankability across the UK. Furthermore, international comparison is also limited, and this makes it difficult to distinguish the unique factors of the UK from those across marine energy ecosystems (Jeffrey, Sedgwick and Gerrard, 2014; Hannon, van Diemen and Skea, 2017). A further weakness is that startup bankability analyses are often drawn from the broader renewable energy sector. However, this creates transferability problems because mature renewable energy technologies, such as solar power, differ significantly from wave energy in industrial structure (Steffen, 2020; Mitchell, Bauknecht and Connor, 2006; Kitzing and Weber, 2014).

3.6.4 Methodological gaps

The literature largely focuses on stakeholder interviews, expert consultation, sector reviews, policy analysis, and cost-performance modelling, and they provide valuable insight, but they tend to examine particular individual parts of the problem rather than explaining the interactions among policy conditions, venture development processes, and financing

decisions. (Bucher et al., 2016; Hannon, van Diemen and Skea, 2017; Polzin et al., 2019; Weber et al., 2017).

Although bankability changes fundamentally over time, longitudinal and mixed-methods research remains limited in this field. The literature seldom examines rejection through investor non-response, unsuccessful funding attempts, early-stage financing failures, and companies that stop operating at the early stages, even though these cases are crucial for understanding the dynamics of bankability.

3.7 Draft research questions

-research question

To what extent do key nuances of bankability for start-up businesses in the UK wave energy sector shape their access to finance?

-research sub-questions

- 1- How does the evaluation of bankability change at different stages of start-up growth?
- 2- Which risks affect investors' willingness to fund UK wave energy start-ups?
- 3- Which market instruments can improve early-stage bankability and preserve innovation incentives?
- 4- How do the business models of wave energy start-ups influence market perceptions of bankability?
- 5- Which strategic measures could enhance the bankability of start-up businesses in the UK wave energy industry?

3.8 Theoretical contribution and managerial implications

The likely DBA contribution of this study lies in integration. The literature already offers important but separate explanations grounded in investor logic, policy credibility, innovation systems, techno economic uncertainty, and governance. The contribution of the present study would be to bring these strands together through a stage sensitive concept of bankability focused on the startup venture.

This study offers three forms of contribution.

Conceptual contribution through a clearer definition of bankability for emerging wave energy ventures.

Analytical contribution through linking startup finance, investor confidence, innovation systems, and techno economic readiness in one explanatory framework.

Applied contribution through identifying which conditions most need to change if startups are to become more financeable in the UK wave ecosystem.

The managerial implications follow from the literature even before primary data are collected. For startup firms, the evidence suggests that financing strategy cannot be separated from

evidence strategy. Ventures need to think not only about technical progress but about what type of evidence different capital providers regard as credible at different stages. For investors and public funders, the literature suggests that judging wave ventures by inappropriate maturity templates may systematically underfund potentially valuable innovation. For policy and support bodies, the implication is that support should not merely increase expenditure, but improve sequencing, reduce avoidable uncertainty, and strengthen the mechanisms through which technical learning becomes bankable.

3.9 Conclusion

This review demonstrates that the financing challenges experienced by wave energy start-up businesses in the United Kingdom cannot be solely attributed to capital scarcity. The literature strongly suggests that ventures continue to struggle to secure financing because the conditions required for bankability are not sufficiently aligned. For example, establishing technical credibility is time-consuming and costly; policy support has often facilitated activity without ensuring long-term market development; ecosystem coordination has often been fragmented; and governance burdens have created additional costs and less-visible liabilities. Consequently, the available finance for start-ups has frequently been inadequately matched to the sector's risk profile and stage of development.

Consequently, the literature is effective to make as a set of partial explanations of a wider bankability problem, but it lacks a collection of distinct debates regarding finance, policy, technology, or regulation. The research opportunity is not simply to reaffirm that wave energy is underfunded; rather, it is to explain how technical, financial, institutional, and regulatory factors interact to determine whether UK wave energy enterprises are viable. This, in turn, shows the necessity of a detailed and stage-sensitive understanding of bankability within the sector.

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Appendix A

Table A1. Theme 1 Bankability, investor confidence, and startup finance

Source	Core argument	Method / Findings	Critical Evaluation	Relevance to the study
Leete, Xu and Wheeler (2013)	UK marine investors focus on barriers and incentives rather than technical promise alone.	Investor survey; revenue certainty, policy credibility and risk reduction matter strongly.	Direct and valuable, but marine-wide rather than startup-specific.	Core anchor for bankability conditions.
Bucher et al. (2016)	Investor confidence depends on top-level drivers of maturity in marine energy.	Expert and systems-based analysis; funding and device performance are mutually dependent.	Strong conceptual bridge, but not UK wave only.	Central to the confidence trap in bankability.
Jeffrey et al. (2015)	Marine energy is blocked at the transition from demonstration to market acceptance.	Sector analysis with systems modelling; array-scale success is the key missing milestone.	Strong on transition logic, thinner on firm-level variation.	Explains the pre-commercial financing gap.
Bucher and Bryden (2016)	The pre-profit phase is the critical bottleneck in marine energy.	Conceptual and empirical sector analysis; array-scale success is treated as a game-changing event.	Useful staging logic, but broad.	Helps frame bankability as phase-specific.
Wiegele and Jones (2024)	Marine energy still struggles to move from public to private capital.	Review of transition evidence; the capital handoff remains weak and under-explained.	Recent and highly relevant, though still sector-wide.	Important contemporary bridge to Part 3.
Polzin et al. (2019)	Renewable policies mobilize finance only when they	Systematic review; credibility and predictability strongly shape investment.	Not wave-specific, but analytically strong.	Key support for policy credibility within bankability.

	address risk and return together.			
Dinica (2006)	Investor perspectives are central to renewable technology diffusion.	Comparative policy analysis; support systems work differently depending on risk exposure.	Older but still influential.	Early conceptual support for financeability logic.
Bürer and Wüstenhagen (2009)	Venture investors prefer policy instruments that reduce regulatory risk.	International survey; policy stability matters for early-stage investment.	Not wave-specific and VC-focused.	Useful for startup finance comparison.
Bürer and Wüstenhagen (2008)	Cleantech VC actors actively manage regulatory risk.	Exploratory empirical analysis; policy risk influences investor behaviour directly.	Exploratory and early.	Helps connect policy risk to startup funding decisions.
Gaddy et al. (2017)	Conventional VC is poorly suited to deep energy hardware ventures.	Comparative investment outcome analysis; deep hardware cleantech consumed capital and returned poorly.	Broad cleantech rather than wave.	Vital for explaining why wave startups fit poorly with standard VC.
Owen et al. (2020)	Early-stage green SMEs need more focused policy and co-finance support.	UK case studies; long-horizon green SMEs are poorly served by existing finance markets.	SME-wide rather than wave-specific.	Strong adjacent evidence for early-stage finance constraints.
Owen (2021)	Government-backed venture capital can help address early-stage low-carbon finance gaps.	Longitudinal qualitative study of UK government VC funds; fund design and learning matter for market building.	Supply-side focus, limited wave specificity.	Useful for public de-risking and patient capital discussion.

Cowling and Liu (2021)	UK cleantech SMEs demand more external capital than standard providers supply.	Large UK firm dataset; traditional finance does not fully meet cleantech demand.	Broad cleantech category.	Strengthens the startup finance side of the framework.
O'Reilly, Mac an Bhaird and Greene (2024)	Equity-backed cleantech firms may move more slowly across the valley of death than assumed.	Longitudinal analysis of 354 UK cleantech firms; equity capital does not automatically speed financial milestones.	Important corrective to simple equity optimism.	Strong recent evidence on early-stage finance.
van der Schans, Owen and Hussain (2025)	Green start-up and scale-up firms face a patient capital problem.	Venture finance analysis; time-horizon mismatch remains severe.	Very recent and promising, though not wave-specific.	Directly supports staged finance fit.
Harrer and Owen (2022)	Information asymmetry in cleantech can be reduced through better performance signalling.	Mixed methods using pitch decks, interviews and documents; value communication affects funding gaps.	Adjacent but sophisticated.	Useful for evidence and signalling within bankability.
McCoy and Schwartz (2022)	Bankability has multiple meanings depending on actor, asset and financing context.	Conceptual and review-based analysis; bankability is relational rather than fixed.	Water rather than energy, but conceptually rich.	One of the best explicit definitions to adapt.
Romero, Sulima and Conibeer (2017)	Novel energy technologies struggle with bankability because financiers judge technology risk differently from developers.	Conceptual/practitioner-oriented analysis; bankability depends on perceived risk ownership.	Lighter empirically, but directly on point.	Useful definitional anchor.

Steffen (2018)	Project finance remains central to renewable deployment.	Review and conceptual analysis; financing structure matters as much as cost.	Stronger on mature projects than startups.	Helps show where wave startups do not yet fit.
Steffen (2020)	Cost of capital differs materially across technologies and contexts.	Review of estimation methods and evidence; renewable financing costs are heterogeneous and consequential.	Not wave-specific, but methodologically strong.	Useful for the cost-of-capital dimension.
Schmidt (2014)	Low-carbon investment risks need targeted de-risking tools.	Conceptual synthesis; different risks require different interventions.	Short but influential.	Useful for structuring public support arguments.
Hall, Foxon and Bolton (2017)	Energy finance should be understood as an adaptive market in transition.	Conceptual and empirical transition analysis; finance evolves with institutions and expectations.	Less direct on startup ventures.	Helps lift the analysis above firm level.
Geddes, Schmidt and Steffen (2018)	State investment banks play multiple roles in low-carbon finance.	Comparative analysis of three countries; public actors can shape markets, not just fill gaps.	Project-development focus dominates.	Useful for policy-backed bankability.
Geddes and Schmidt (2020)	Transition studies underplay the role of finance in niche-regime interactions.	56-interview study; niches either fit financial regime expectations or stretch the regime.	Not sector-specific enough on wave.	Major theoretical support for Part 3.
Murphy and Edwards (2003)	Emerging technologies face a valley of death between public and private funding.	Conceptual policy analysis; transition stages are structurally fragile.	Classic but broad.	Important historical anchor for staged finance.

Vaan (2009)	The valley of death is too narrow unless wider socio-technical factors are included.	Case-based conceptual analysis; financing problems reflect wider system conditions.	Not wave-specific, but conceptually useful.	Supports ecosystem-based bankability.
Hafner et al. (2020)	The green finance gap is systemic rather than simply transactional.	Conceptual and empirical synthesis; fragmented systems hinder green capital flows.	Broad.	Helps position bankability within wider finance systems.
van den Burg et al. (2017)	Blue growth sectors struggle to mobilize investors without credible de-risking.	Sector analysis; investor diversity matters.	Marine-wide and strategic rather than venture-specific.	Useful adjacent marine finance evidence.

Source: Author's synthesis based on the reviewed literature.

Appendix B

Table B1. Theme 2 Policy support, revenue certainty, and market formation

Source	Core argument	Method / Findings	Critical Evaluation	Relevance to the study
Allan et al. (2011)	Differentiated ROC support was crucial because wave and tidal costs were far above mature technologies.	Economic modelling; finds that banding materially affects viability.	Early policy context, but still central.	Key source on revenue credibility.
Allan, McGregor and Swales (2009)	Banded ROCs materially alter cost competitiveness for marine energy.	Policy-economic analysis; finds support intensity changes bankability prospects.	Older but foundational.	Early evidence on why generic support failed.
Watson and Fulcher (2010)	UK policy from 2000 to 2009 supported activity but left structural weaknesses.	Policy review; finds support was significant but uneven.	Historic window only.	Useful background on policy formation.
Bunn and Yusupov (2015)	Replacing ROCs with CfDs created inefficiencies for UK renewables.	Policy analysis; finds support transition may worsen incentives for emerging technologies.	System-level rather than wave-only.	Useful for policy risk discussion.
Lockwood (2016)	The Levy Control Framework increased uncertainty through budget control effects.	Policy analysis; finds budget mechanisms can amplify investor risk.	Broader renewable focus.	Strong evidence on policy credibility.
Kozlov (2014)	CfD design leaves generators exposed to several risks.	Policy risk analysis; finds support instruments can	Not wave-specific.	Helps explain why support may not equal bankability.

		transfer rather than remove uncertainty.		
Gürkan and Langestraat (2014)	Banding and obligation design influence technology incentives.	Modelling analysis; finds policy mechanics shape technology pathways.	Technical policy focus.	Useful for support scheme interpretation.
Mitchell, Bauknecht and Connor (2006)	Renewable policies differ in how they reduce investor risk.	Comparative policy analysis; finds support effectiveness depends on risk exposure.	Classic but dated.	Strong conceptual anchor on risk-reducing policy.
Kitzing and Weber (2014)	Risk exposure varies across support mechanisms.	Comparative analysis; finds policy instruments alter risk allocation.	Broad renewable focus.	Useful for de-risking logic.
Welisch and Poudineh (2019)	UK offshore wind auctions illustrate how mature sector policy attracts capital.	Policy and auction analysis; finds clear market design can lower uncertainty.	Transfer to wave is limited.	Useful comparison point.
Connor (2012)	The UK Renewables Obligation shaped renewable deployment through certificate incentives.	Policy overview; finds support architecture matters for investment.	Descriptive but useful.	Background on support regime evolution.
Harrison (2008)	Scottish and UK support mechanisms mattered for marine energy emergence.	Policy review; finds early mechanism design shaped sector opportunity.	Early-stage evidence.	Useful for historical policy context.

Willis et al. (2010)	UK marine policy created ambition but not full commercial traction.	Review; finds support and development remained uneven.	Overview rather than deep critique.	Useful bridge source.
Jeffrey, Sedgwick and Gerrard (2014)	Public funding design differs across the UK and US.	Comparative policy analysis; finds funding structure influences commercialization pathways.	National comparison more than startup focus.	Useful for support design lessons.
Jeffrey, Jay and Winskel (2013)	Marine energy needs coordinated support to accelerate development.	Sector analysis; finds benefits and challenges are tightly coupled.	Broad.	Useful for policy and commercialization linkage.
Jeffrey and Winskel (2009)	UK ocean energy policy ambition outpaced commercial readiness.	Sector perspective; finds strategic value does not guarantee deployment.	Early and strategic.	Useful for policy ambition versus bankability.
Wang et al. (2024)	Banding remains a pivotal issue in UK support design.	Recent reassessment; finds support calibration still matters for emerging renewables.	More general than wave specific.	Useful recent policy update.

Source: Author's synthesis based on the reviewed literature.

Appendix C

Table C1. Theme 3 Innovation systems and ecosystem coordination

Source	Core argument	Method / Findings	Critical Evaluation	Relevance to the study
Hannon, van Diemen and Skea (2017)	UK wave support failed because it pushed commercialization too fast and learned too little.	Major policy and sector study; finds fragmentation, over-optimism, and weak knowledge retention were central problems.	Landmark source, though historically anchored.	Probably the single most important ecosystem paper.
Jin and Greaves (2021)	UK wave energy retains strong resource potential but weak commercialization progress.	Review plus stakeholder consultation; finds technical promise persists despite slow commercial advance.	Broad review, less bankability specific.	Current sector overview.
Winskel et al. (2006)	Marine energy innovation is shaped by energy policy and institutional context.	Conceptual and empirical system analysis; finds institutional misfit constrains development.	Seminal but older.	Core theory anchor.
Winskel (2007)	Marine energy depends on both financial and social capital.	Sector analysis; finds network strength matters alongside finance.	Less direct on startups.	Strong ecosystem interpretation.
Corsatea (2014)	Synergies between institutions and developers are essential in marine energy.	Empirical sector analysis; finds coordination and experimentation matter for crossing the valley of death.	Useful but not wave-only.	Supports ecosystem credibility.

Vantoch-Wood (2012)	UK wave innovation systems can be mapped through functional methods.	Methodological application; system functions reveal bottlenecks.	Method-heavy.	Useful for analytical framing.
Vantoch-Wood and Connor (2013)	Wave policy networks shape the sector's support dynamics.	Policy network mapping; finds institutions and relationships affect development.	Indirect on finance.	Helps unpack coordination gaps.
Foxon et al. (2005)	UK renewables suffer from systems failures, not just market failures.	Conceptual and policy analysis; finds coordination and institutional barriers are persistent.	Broad renewable scope.	Seminal background source.
Winskel et al. (2014)	UK energy innovation governance has become fragmented and weakly aligned.	Policy analysis; finds system reform did not resolve deeper coordination problems.	Broad energy focus.	Useful contextual support.
Hannon, Skea and Rhodes (2014)	Innovation intermediaries coordinate UK energy innovation.	Empirical analysis of intermediaries; finds they can reduce fragmentation.	Not wave-only.	Useful for ecosystem support bodies.
Gallagher et al. (2012)	Energy technology innovation systems require joined analysis of actors and institutions.	Conceptual review; finds market formation and system functions matter together.	Conceptual rather than empirical.	Key theory support.
Negro (2007)	Sustainable innovation depends on system functions interacting over time.	Conceptual development; finds weak functions slow sector emergence.	Generic.	Useful for interpreting wave stagnation.

Suurs and Hekkert (2009)	Transitions are driven by combinations of system functions.	Conceptual synthesis; finds formative stages require reinforcing dynamics.	Not finance-specific.	Useful for commercialization pathway logic.
Dewald and Truffer (2017)	Market formation is a critical but underdeveloped function in transitions.	Conceptual and empirical analysis; finds early markets need deliberate shaping.	Not wave-specific.	Useful for revenue pathway arguments.
Al-Saleh (2010)	National renewable industries develop through systems of innovation.	Comparative synthesis; finds industrial emergence depends on institutions and learning.	Broad.	Supports ecosystem perspective.
Lawrence et al. (2013)	The UK marine sector had strategic assets but uneven commercialization capability.	Sector overview; finds institutional support did not guarantee market success.	Descriptive.	Factual sector map.
Jeffrey (2007)	UK wave and tidal progress depended on coordinated support and technical development.	Sector review; finds progress remained fragile.	Early baseline.	Historical context.
Kingston (2017)	Later commentary confirms the support-failure diagnosis of UK wave innovation.	Commentary; finds UK support misread commercialization needs.	Derivative but useful.	Supports continued debate.
Iskandarova and Simakova (2012)	Wave Hub became shaped by expectations, expertise, and projected futures.	Case analysis; finds expectations can outrun practical readiness.	One case.	Useful on credibility and hype.

Iskandarova (2016)	Policy development is driven by agency and actor networks, not scale alone.	Qualitative policy analysis; finds policy outcomes are socially assembled.	More theoretical than finance oriented.	Useful for contextual interpretation.
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Source: Author's synthesis based on the reviewed literature.

Appendix D

Table D1. Theme 4 Techno-economic readiness and commercialisation pathways

Source	Core argument	Method / Findings	Critical Evaluation	Relevance to the study
MacGillivray, Jeffrey and Wallace (2015)	Iteration and deployment are central to wave and tidal innovation.	Sector innovation analysis; finds repeated deployment is needed to mature technology.	Strong learning logic, limited finance detail.	Important for staged evidence creation.
MacGillivray et al. (2014)	Cost reduction in marine renewables depends on learning investment.	Modelling analysis; finds deployment and innovation spending are linked.	Model assumptions matter.	Helps explain why early finance is so consequential.
Guo and Ringwood (2021)	Wave technology remains commercially immature and fragmented.	Technical and commercial literature review; finds lack of convergence and repeated firm failure weaken investor trust.	One of the best recent overviews.	Strong direct support for commercialization weakness.
Uihlein and Magagna (2016)	Ocean energy research must move beyond technology alone.	Review; finds non-technical and commercial barriers are crucial.	Broad sector lens.	Useful bridge source.
Magagna and Uihlein (2015)	Ocean energy in Europe faces persistent market and administrative barriers.	European sector review; finds technology progress alone is insufficient.	Europe-wide rather than UK-specific.	Comparative perspective.
Magagna, Monfardini and Uihlein (2018)	Ocean energy needs continued learning investment and strategic	Policy and sector review; finds commercialization	Strategic rather than venture-level.	Helps frame policy and cost learning.

	deployment support.	requires long-horizon backing.		
Magagna et al. (2014)	Moving from development to market requires a staged strategic agenda.	Strategic technology agenda; finds roadmap alignment matters.	Programmatic.	Useful for pathway thinking.
Astariz and Iglesias (2015)	Wave energy economics remain weak relative to alternatives.	Review; finds costs and uncertainty remain high.	Broad economic framing, not startup-focused.	Useful on competitiveness limits.
Astariz and Iglesias (2016)	Wave economics compare poorly with other power options without significant improvement.	Reassessment analysis; finds competitiveness challenges are deep.	Cost-oriented.	Important for finance credibility.
Stegman et al. (2017)	Large cost reductions are needed for marine energy to enter the least-cost UK system.	Whole-systems model; finds deployment depends on major improvement.	System rather than venture lens.	Useful on commercialization thresholds.
Kerr et al. (2021)	Radical innovation may be more valuable than deployment-led incremental learning alone.	Modelling and policy analysis; finds support needs can become excessive without stronger innovation.	Abstracted from firm-level realities.	Useful on long-term bankability logic.
Ruiz-Minguela et al. (2022)	Future wave costs remain highly uncertain.	Cost estimation study; finds uncertainty remains wide even in future projections.	Modelling uncertainty is itself a result.	Useful for investor caution.

Têtu and Fernández Chozas (2021)	Early-stage economic assessment of WECs needs better guidance.	Guidance proposal; finds inconsistent assessment practices hinder comparability.	Methodological rather than empirical.	Useful for evidence quality gap.
Pennock et al. (2022)	Future cost targets can be used to infer current design requirements.	Case studies in offshore renewables; finds back-casting can guide development priorities.	Indirect on finance.	Useful for commercialization planning.
Andres et al. (2017)	Reversed LCOE calculations help define design constraints for commercialization.	Techno-economic modelling; finds design choices are linked to commercial thresholds.	Model-dependent.	Useful for technical credibility.
Weber (2012)	TRL alone is insufficient for wave technology development.	Framework development; finds performance level must accompany readiness level.	Framework rather than outcome evidence.	Highly useful for bankability metrics.
Weber, Costello and Ringwood (2013)	WEC technology performance levels provide a better economic development metric.	Metric development; finds success depends on performance progression, not just readiness.	Technical framework.	Important for evidence and signalling.
Weber et al. (2017)	Different development trajectories vary sharply in cost, time, and risk.	Comparative trajectory assessment; finds performance-first pathways may reduce failure risk.	Scenario-based.	Valuable for staged commercialization decisions.
O'Connor, Lewis and Dalton (2013a)	Pelamis and Wavestar perform differently by location and rating.	Comparative simulation; finds commercial performance is site- and design-dependent.	Case-specific.	Useful on project heterogeneity.

Gray et al. (2017)	Reliability and O&M are highly site-sensitive in wave converters.	Sensitivity analysis; finds maintenance context strongly affects economics.	Technical but finance-relevant.	Useful on operational bankability.
Topper et al. (2019)	Cost-of-energy variability remains a major issue for ocean energy arrays.	Modelling analysis; finds variability itself is a risk source.	Array focus.	Useful for finance uncertainty.
O'Connor, Lewis and Dalton (2013b)	Operating expenditure materially affects financial returns in wave projects.	Financial modelling; finds OPEX uncertainty can damage returns substantially.	Project-level.	Strong for revenue and cost credibility.
Renzi et al. (2021)	Niche applications may provide more realistic pathways for some wave technologies.	Application review; finds not all paths need immediate utility-scale competition.	Still speculative in places.	Useful alternative pathway source.
Bertram et al. (2020)	Device suitability and site matching matter for commercial viability.	Feasibility and selection analysis; finds misfit can destroy viability.	Engineering-heavy.	Useful for bankability conditions.
Iglesias, Astariz and Vázquez (2018)	Wave and tidal economics remain heavily contingent on technical and deployment assumptions.	Review; finds uncertainty remains intrinsic.	Broad overview.	Useful background economics.
Future Marine Energy Challenge (c.2000)	Early UK expectations for marine cost reduction were ambitious.	Early challenge assessment; finds long-standing optimism may have set unrealistic benchmarks.	Dated but revealing.	Useful historical baseline.

Source: Author's synthesis based on the reviewed literature.

Appendix E

Table E1. Theme 5 “Risk, due diligence, and staged investment”

Source	Core argument	Method / Findings	Critical Evaluation	Relevance to the study
Andres et al. (2017)	Ocean energy attractiveness cannot be judged by LCOE alone.	Comparative assessment; finds wider risk and deployment factors matter.	Broad but important corrective.	Supports multidimensional bankability.
Hutcheson, Andres and Jeffrey (2016)	Investment in marine energy should be judged through risk versus reward, not cost only.	Methodology paper; finds low-cost designs can still be unattractive if risk is too high.	Framework rather than market evidence.	Strong for investor judgment logic.
Wilson, Rowley and Watson (2011)	Due diligence in renewables should assess the whole system, not only the device.	Framework development; finds grid, logistics, permits, and developer capability all matter.	More project than startup oriented.	Excellent for whole-system bankability.
Shah et al. (2017)	Improved uncertainty analysis can de-risk marine energy project development.	Uncertainty analysis; finds better modelling can reduce financing ambiguity.	Project-level and technical.	Useful for credible evidence discussion.
Shah (2018)	Refined uncertainty analysis improves tidal investment cases.	Quantitative analysis; finds better treatment of uncertainty changes perceived value.	Tidal rather than wave.	Useful analogue for confidence building.
Guanche et al. (2014)	Financial indicators for wave farms are highly sensitive to uncertainty.	Modelling; finds variance in assumptions affects returns sharply.	Farm-level rather than startup-level.	Supports investor caution.

Stallard, Ricci and Parque Tecnológico (2009)	Marine energy schemes require more careful economic assessment methods.	Methodological review; finds assessment choice affects viability conclusions.	Method-focused.	Useful for evidence quality.
MacDougall (2017)	Tidal financing impasse can be approached through staged international investment.	Strategic finance analysis; finds timing and stage sequencing matter.	Tidal analogue, not wave-direct.	Strong on financing pathway logic.
MacDougall (2018)	Investors may rationally delay commercial-scale tidal decisions.	Real-options style analysis; finds waiting can be financially rational under uncertainty.	Tidal-specific.	Useful for why finance may stall even with promise.
Stallard, Rothschild and Aggidis (2008)	Large-scale wave schemes are highly sensitive to economic assumptions.	Modelling; finds viability depends on uncertain parameters.	Early modelling.	Historical risk evidence.
Jude et al. (2017)	Ocean energy investment is shaped by multiple layers of risk.	Review/synthesis; finds technical, market, and institutional risks interact.	Broad.	Useful umbrella source.
Martins (2014)	Ocean project feasibility requires structured risk assessment.	Risk framework; finds multiple categories of uncertainty affect feasibility.	Method-oriented.	Useful for appraisal logic.
Gueguen (2016)	Marine energy projects need integrated risk assessment.	Risk assessment; finds financeability depends on risk visibility and management.	Tool-oriented.	Useful supporting source.

Ericsson and Gregorson (2018)	Quantitative risk assessment can clarify wave technology uncertainty.	Quantitative risk study; finds some risks can be measured more clearly than assumed.	Technical orientation.	Useful for evidence development.
Gross, Blyth and Heptonstall (2010)	Electricity investment policy must look beyond generation cost to risks and revenues.	Conceptual policy analysis; finds risk structure shapes technology choice.	Not wave-specific.	Strong broad finance logic.
Kitzing (2014)	Support instruments expose investors to different risk profiles.	Comparative modelling; finds policy design directly shapes investor risk.	Renewable-wide.	Useful for risk allocation.
Nightingale et al. (2016)	Different financiers fund different stages and technologies.	Sector finance analysis; finds investor type matters to technology pathways.	Not wave-focused.	Important for stage-sensitive bankability.

Source: Author's synthesis based on the reviewed literature.

Appendix F

Table F1. Theme 6 “Governance, consenting, and non-technical barriers”

Source	Core argument	Method / Findings	Critical Evaluation	Relevance to the study
Wright (2016)	Scottish marine governance creates important non-technical barriers for wave and tidal development.	Industry perspective; finds governance complexity affects project progress.	Strong direct evidence, though Scotland-focused.	Core source on regulatory barriers.

O'Hagan et al. (2016)	European wave progress has been slowed by administrative and practical non-technical barriers.	Sector review; finds progress depends on more than technology alone.	Broad and comparative.	Useful overview of wider non-technical constraints.
Greaves et al. (2016)	EIA experience from European wave test centres reveals recurring approval challenges.	Experience review; finds environmental assessment remains a practical hurdle.	Test-centre based rather than full commercial scale.	Useful on approval process realities.
Harrington and Andina-Pendás (2008)	Wave Hub planning consent required substantial environmental appraisal and stakeholder negotiation.	Case analysis; finds consent processes shape project development.	One major case.	Useful on UK consent complexity.
Greaves et al. (2013)	Streamlining administrative processes is necessary for sector progress.	Policy/practice-oriented discussion; finds process burden slows deployment.	More reform-oriented than analytical.	Useful on procedural barriers.
Norris (2009)	EMEC helped develop targeted monitoring and more streamlined consents.	Test-centre experience; finds support infrastructure can reduce consenting friction.	Facility-specific.	Useful on enabling institutions.
Witt et al. (2012)	Biodiversity concerns and environmental evidence are central to wave energy approvals.	Wave Hub-related assessment; finds ecological evidence requirements are substantial.	Strong on environmental dimension, less on finance.	Useful for regulatory evidence burden.

Simas et al. (2000/undated)	Ocean energy consenting is hindered by complex and diverse legal processes.	Comparative review; finds lack of tailored frameworks slows progress.	Broad European lens.	Useful umbrella source on consenting complexity.
Mackie and Velenturf (2021)	Decommissioning security requirements create long-tail financial and regulatory risk.	Policy analysis; finds uncertainty around decommissioning finance can expose public and private actors.	More offshore-renewables-wide than wave-specific.	Important for hidden liability risk.
Simas et al. (2012)	Stakeholder engagement shapes the consenting process materially.	Survey-based analysis; finds sensitivities differ across stakeholder groups.	Engagement-focused.	Useful on legitimacy and approval risk.
Caine (2019)	Offshore renewable consenting can fail to assess cumulative impacts adequately.	Legal analysis; finds fragmented processes weaken impact assessment.	Broader offshore scope.	Useful on regulatory complexity.
Leary and Esteban (2009)	Regulatory uncertainty is a major barrier to ocean energy development.	Legal-policy analysis; finds domestic regulation remains underdeveloped.	Early but influential.	Strong on regulatory uncertainty.
Neumann et al. (2006)	Licensing and environmental issues are major non-technical barriers to commercial wave projects.	Experience review; finds permit complexity rises as projects move toward commercialization.	Early-stage evidence.	Important historical baseline.

West, Bailey and Whitehead (2019)	Stakeholder perceptions of Wave Hub show that local legitimacy cannot be assumed.	Stakeholder study; finds concerns about benefits and impacts remain salient.	Case-specific.	Useful on social acceptance and credibility.
Zeuschner (2011)	The Scottish consenting regime evolved to address offshore renewable needs, but remained demanding.	Legal/policy review; finds regulatory development is ongoing.	Descriptive.	Useful contextual source.
Peplinski et al. (2021)	Environmental permitting and compliance costs can be substantial.	Cost analysis; finds permitting can take a significant share of project cost.	U.S.-based, not UK-specific.	Strong supporting evidence on soft-cost burden.
Smith et al. (2009)	Wave Hub and related research infrastructure aimed to reduce development friction through support and coordination.	Infrastructure case study; finds test centres can support commercialization ecosystems.	More enabling context than critique.	Useful on ecosystem support capacity.

Source: Author's synthesis based on the reviewed literature.

Appendix G

Table G1. Theme 1 Patterns and Contradictions: Bankability, investor confidence, and startup finance

Area	Pattern / contradiction	Explanation	Key References
Pattern 1	Finance depends on credible staged evidence	Access to finance depends less on headline capital need than on whether ventures can present stage-appropriate evidence of technical progress, commercial promise, and risk reduction.	Leete, Xu and Wheeler (2013); Bucher et al. (2016); McCoy and Schwartz (2022)
Pattern 2	The public-to-private transition is the weakest point	Many ventures can secure early support but struggle to move into larger-scale commercial finance.	Jeffrey et al. (2015); Bucher and Bryden (2016); Wiegele and Jones (2024)
Pattern 3	Policy credibility matters directly for bankability	Stable and predictable policy affects investor confidence by shaping both expected return and perceived risk.	Dinica (2006); Börer and Wüstenhagen (2009); Polzin et al. (2019)
Pattern 4	Finance model fit matters as much as capital volume	The problem is not only insufficient capital, but mismatch between available finance models and long-horizon deep hardware ventures.	Gaddy et al. (2017); Owen et al. (2020); van der Schans, Owen and Hussain (2025)
Pattern 5	Information asymmetry and signalling remain central	Investors rely on maturity signals and performance narratives, so weak signalling can worsen funding gaps.	Bucher et al. (2016); Harrer and Owen (2022)

Contradiction 1	Investor caution vs finance system failure	Some studies suggest investors are rationally cautious because risk is genuinely high, while others argue the finance system is poorly designed for such ventures.	Leete, Xu and Wheeler (2013); Bucher et al. (2016); Gaddy et al. (2017)
Contradiction 2	More equity is not always the solution	Earlier assumptions often favour more private capital, but newer work suggests equity-backed firms do not necessarily progress faster.	O'Reilly, Mac an Bhaird and Greene (2024); Owen (2021)
Contradiction 3	Cleantech lessons may not transfer cleanly to wave energy	Wave energy shares features with broader cleantech, but marine hardware conditions may make financing problems more severe or different in kind.	Owen et al. (2020); Cowling and Liu (2021); Wiegele and Jones (2024)
Contradiction 4	Bankability as venture issue vs ecosystem issue	Some work implies bankability is mainly judged at firm level, while other studies show it is also shaped by wider policy and finance-system conditions.	McCoy and Schwartz (2022); Geddes and Schmidt (2020); Hafner et al. (2020)

Source: Author's synthesis based on the reviewed literature.

Appendix H

Table H1. Theme 2 Patterns and Contradictions: Policy support, revenue certainty, and market formation

Area	Pattern / contradiction	Explanation	Key References
Pattern 1	Revenue support design strongly shapes viability	Support intensity and structure affect whether emerging technologies can appear commercially credible.	Allan et al. (2011); Allan, McGregor and Swales (2009)
Pattern 2	Policy credibility matters as much as policy generosity	Investors respond not only to support levels but to stability, predictability, and risk allocation.	Mitchell, Bauknecht and Connor (2006); Kitzing and Weber (2014); Polzin et al. (2019)
Pattern 3	UK policy often supported activity without securing market formation	Policy encouraged experimentation, but did not always create a durable route to commercialization.	Watson and Fulcher (2010); Jeffrey, Jay and Winskel (2013); Willis et al. (2010)
Pattern 4	Budget and contract design can amplify uncertainty	Support instruments may shift or repackage risk rather than remove it.	Lockwood (2016); Kozlov (2014); Bunn and Yusupov (2015)
Contradiction 1	Support exists, but bankability remains weak	Significant policy intervention did not consistently translate into financeable ventures.	Allan et al. (2011); Lockwood (2016); Jeffrey and Winskel (2009)
Contradiction 2	Policy ambition vs commercial readiness	Strategic ambition for ocean energy often outpaced the sector's actual maturity.	Jeffrey and Winskel (2009); Watson and Fulcher (2010)

Contradiction 3	Mature-sector policy lessons do not transfer neatly	Offshore wind policy success offers comparison, but wave energy faces different maturity and risk conditions.	Welisch and Poudineh (2019); Kitzing and Weber (2014)
Contradiction 4	More reform did not always mean less risk	Changes from ROCs to CfDs were presented as improvements yet often introduced new uncertainty for emerging technologies.	Bunn and Yusupov (2015); Kozlov (2014); Lockwood (2016)

Source: Author's synthesis based on the reviewed literature.

Appendix I

Table I1. Theme 3 Patterns and Contradictions: Innovation systems and ecosystem coordination

Area	Pattern / contradiction	Explanation	Key supporting studies
Pattern 1	Bankability is ecosystem-bound, not firm-bound	Financing prospects depend on institutions, networks, learning, and support structures beyond the startup itself.	Hannon, van Diemen and Skea (2017); Winskel et al. (2006); Corsatea (2014)
Pattern 2	Fragmentation weakens commercialization	Weak coordination, poor knowledge retention, and institutional misalignment slow sector progress.	Hannon, van Diemen and Skea (2017); Winskel et al. (2014); Foxon et al. (2005)
Pattern 3	Social capital matters alongside financial capital	Collaborative learning and network strength are important to sector development.	Winskel (2007); Winskel et al. (2006)
Pattern 4	Market formation is a missing system function	Emerging sectors need deliberate shaping of markets, not only technology support.	Gallagher et al. (2012); Dewald and Truffer (2017); Negro (2007)
Contradiction 1	Strong resource potential vs weak commercialization	The UK retains major wave energy potential, yet commercial progress remains limited.	Jin and Greaves (2021); Lawrence et al. (2013)
Contradiction 2	Public support vs poor outcomes	Considerable support and infrastructure did not generate sustained sector success.	Hannon, van Diemen and Skea (2017); Kingston (2017)

Contradiction 3	Expectations vs practical readiness	High expectations and strategic narratives often moved faster than technical and commercial readiness.	Iskandarova and Simakova (2012); Jin and Greaves (2021)
Contradiction 4	Strong systems theory, weaker finance connection	Innovation systems studies explain coordination failures well but often link them only indirectly to actual financing decisions.	Gallagher et al. (2012); Suurs and Hekkert (2009); Corsatea (2014)

Source: Author's synthesis based on the reviewed literature.

Appendix J

Table J1. Theme 4 Patterns and Contradictions: Techno-economic readiness and commercialisation pathways

Area	Pattern / contradiction	Explanation	Key supporting studies
Pattern 1	Deployment and iteration are essential to maturity	Repeated deployment generates learning, cost reduction, and stronger technical evidence.	MacGillivray, Jeffrey and Wallace (2015); MacGillivray et al. (2014)
Pattern 2	Techno-economic evidence remains weak and uneven	Costs, performance, and reliability remain uncertain, making commercialization hard to justify.	Guo and Ringwood (2021); Astariz and Iglesias (2015); Ruiz-Minguela et al. (2022)
Pattern 3	TRL alone is not enough	Readiness must be matched with performance and economic evidence to be meaningful for commercialization.	Weber (2012); Weber, Costello and Ringwood (2013); Têtu and Fernández Chozas (2021)
Pattern 4	Reliability, O&M, and site conditions matter materially	Commercial viability is highly sensitive to maintenance conditions, site characteristics, and operational performance.	Gray et al. (2017); O'Connor, Lewis and Dalton (2013b); Bertram et al. (2020)
Pattern 5	Alternative pathways may matter	Niche applications and flexible commercialization routes may offer more realistic near-term progress than immediate utility-scale competition.	Renzi et al. (2021); Magagna et al. (2014)

Contradiction 1	Learning needs finance, but finance needs learning evidence	Technologies require deployment funding to improve, yet funders often want stronger evidence before investing.	MacGillivray et al. (2014); MacGillivray, Jeffrey and Wallace (2015); Guo and Ringwood (2021)
Contradiction 2	Technical promise vs commercial immaturity	Strong resource and engineering potential persists, but commercial readiness remains weak.	Guo and Ringwood (2021); Uihlein and Magagna (2016); Magagna and Uihlein (2015)
Contradiction 3	Incremental learning vs radical innovation	Some studies support deployment-led cost reduction, while others argue radical innovation may offer more value.	MacGillivray et al. (2014); Kerr et al. (2021)
Contradiction 4	Economic models offer guidance, but also reinforce uncertainty	Modelling clarifies targets and constraints, yet future costs and pathways remain highly assumption dependent.	Stegman et al. (2017); Andres et al. (2017); Ruiz-Minguela et al. (2022)

Source: Author's synthesis based on the reviewed literature.

Appendix K

Table K1. Theme 5 Patterns and Contradictions: Risk, due diligence, and staged investment

Area	Pattern / contradiction	Explanation	Key supporting studies
Pattern 1	LCOE alone is insufficient	Investment attractiveness depends on wider technical, operational, and market risks, not cost only.	Andres et al. (2017); Hutcheson, Andres and Jeffrey (2016)
Pattern 2	Due diligence is whole-system, not device-only	Grid, logistics, permits, and developer capability affect financeability alongside technology performance.	Wilson, Rowley and Watson (2011)
Pattern 3	Uncertainty analysis materially shapes project attractiveness	Better handling of uncertainty can change yield, return, and risk estimates.	Guanche et al. (2014); Shah et al. (2017); Shah (2018)
Pattern 4	Investor timing matters under uncertainty	Delaying investment can be economically rational when risks remain unresolved.	MacDougall (2017); MacDougall (2018)
Pattern 5	Risk is layered and heterogeneous	Technical, market, policy, and institutional risks interact rather than operating separately.	Jude et al. (2017); Gross, Blyth and Heptonstall (2010)
Contradiction 1	Better modelling may reduce ambiguity, but not remove risk	Improved appraisal methods can clarify uncertainty, yet high underlying risk may still deter finance.	Shah et al. (2017); Guanche et al. (2014)

Contradiction 2	Strong appraisal frameworks, weak behavioural evidence	The literature explains how risk should be assessed better than how investors actually assess it in practice.	Wilson, Rowley and Watson (2011); Stallard, Ricci and Parque Tecnológico (2009)
Contradiction 3	Rational delay can protect investors but stall sector progress	Waiting may be financially sensible for investors, but damaging for commercialization and learning.	MacDougall (2018); Gross, Blyth and Heptonstall (2010)
Contradiction 4	Broad renewable finance logic is useful, but not wave-specific	General studies on policy risk and financier heterogeneity help interpretation, but may not fully capture marine energy conditions.	Kitzing (2014); Nightingale et al. (2016)

Source: Author's synthesis based on the reviewed literature.

Appendix L

Table L1. Theme 6 Patterns and Contradictions: Governance, consenting, and non-technical barriers

Area	Pattern / contradiction	Explanation	Key supporting studies
Pattern 1	Consenting is a major non-technical barrier	Licensing, EIA, and regulatory approvals add delay, uncertainty, and cost.	Wright (2016); Leary and Esteban (2009); Neumann et al. (2006)
Pattern 2	Environmental evidence requirements are substantial	Monitoring and biodiversity assessment create real evidential burdens for developers.	Greaves et al. (2016); Witt et al. (2012); Harrington and Andina-Pendás (2008)
Pattern 3	Stakeholder legitimacy affects development prospects	Public and stakeholder perceptions influence approval risk and project credibility.	Simas et al. (2012); West, Bailey and Whitehead (2019)
Pattern 4	Support infrastructure can reduce friction	Test centres and intermediaries can help streamline processes and build evidence.	Norris (2009); Smith et al. (2009)
Pattern 5	Hidden long-tail liabilities matter	Decommissioning and compliance obligations affect project risk beyond initial deployment.	Mackie and Velenturf (2021); Peplinski et al. (2021)
Contradiction 1	Marine renewables are promoted as low-carbon solutions, yet face heavy regulatory burdens	Strategic policy support coexists with slow, demanding approval pathways.	Wright (2016); Caine (2019); Leary and Esteban (2009)

Contradiction 2	Streamlining is advocated, but complexity persists	Many studies call for simplification, yet evidence suggests burdens remain entrenched.	Greaves et al. (2013); Simas et al. (2000/undated); Zeuschner (2011)
Contradiction 3	Support infrastructure helps, but does not remove systemic barriers	Facilities like EMEC and Wave Hub reduce some frictions but cannot solve wider governance issues alone.	Norris (2009); Smith et al. (2009); West, Bailey and Whitehead (2019)
Contradiction 4	The literature identifies governance burdens clearly, but links to finance only indirectly	Non-technical barriers are well documented, yet their direct effect on investor decisions is less developed.	Wright (2016); Mackie and Velenturf (2021); Peplinski et al. (2021)

Source: Author's synthesis based on the reviewed literature.