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New firms developing novel technology in a complex emerging industry

The road towards commercialization of renewable marine energy technologies

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Thesis for the degree of Philosophiae Doctor

Trondheim, June 2016

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Summary

This thesis addresses new technology firms in a complex emerging industry. Emerging industries are industries in the earliest stages where new firms often are important participants because of their introduction of new innovative ideas and technologies (e.g. Giarratana, 2004; Hill & Rothaermel, 2003). New technology firms typically struggle with limited resources related to funding, technology expertise and network. However, in emerging industries new firms are also challenged by a limited socio-political legitimacy compared to firms operating within existing industries (Aldrich & Fiol, 1994). Thus, new technology firms in emerging industries are challenged by their own liability of newness, the industry's lack of legitimacy and structure, and the new technology's inherent uncertainty (Woolley, 2014). This thesis focuses on how new firms can overcome these challenges in the commercialization of novel and capital-intensive technology in a complex emerging industry by interacting with partners, financiers, customers and policy makers.

The context of the research has been the emerging marine energy industry, which consists of firms developing devices to harness energy from ocean waves and tides. No technologies are yet commercially viable in this industry, however, and the central challenges for firms are lack of capital, technology development and available infrastructure (Krohn et al., 2013; OES, 2015).

Through multiple-case studies of firms within the marine energy industry, the four individual papers of the thesis have addressed different aspects related to the commercialization of novel technologies in an emerging industry. The first paper studies the international activities of new firms in an emerging industry. More specifically, it investigates the extent of early internationalization among Norwegian marine energy firms, and how their use of internationalization to access resources such as funding and technology competence through investors, companies and public programs, help them to further develop their technology towards commercialization.

The second paper contributes to the understanding of investors' non-financial involvement in new technology firms in the early stages of an emerging industry, and focuses on the positive contributions of different types of investors such as business angels (BAs), Venture Capitalists (VCs) and larger corporations (CVC). The paper finds that for technology developing ventures in an emerging industry, the most important contributions are when investors, actively or passively, help attract new resources.

The third paper studies how new technology firms organize their technology development and manufacturing of components and devices in the context of the emerging marine energy industry. The study proposes and discusses three different supply chain configurations for new firms in emerging industries. Furthermore, the paper highlights the difficulty of engaging suppliers when

operating in the early stages of an emerging industry, before any dominant technological design has appeared and technological standards are present.

The fourth paper studies the entry of large multinational companies (MNCs) in the emerging tidal energy industry. More specifically, it finds that firms assess the uncertainties related to entering an emerging industry differently, and that these assessments combined with the firms' pre-entry resources, the degree of competitiveness and the preferences of the firms being invested in decide whether the MNC choose an entry mode giving flexibility (minority investments) or control (internal development and acquisition).

Based on the findings from the individual papers, the thesis suggest a model of how strategic decisions and interactions with external stakeholders can help new technology firms through the increasingly more complex and expensive technology development process towards commercialization. The model divides the commercialization process in the marine energy industry into three specific technological and financial gaps: 1) 'From laboratory to scale models', 2) 'From scale models to the real world', and 3) 'Towards commercialization'. These gaps are increasingly more technologically advanced and capital demanding, and it is discussed how different investors and strategies related to internationalization and supply chain configuration, can be important to overcome these gaps. In addition, the model also summarizes where in the commercialization process the findings of the four different papers contribute and how they are connected. Finally, implications for research, managers and policy makers are discussed.

Acknowledgements

Although it is my name on the front cover of this thesis, this work was not possible without the contributions of several people who have been important for me during the last five years. A special thank you goes to my supervisor, Øystein Moen. Øystein has provided valuable guidance in the academic writing process, given me a lot of freedom and flexibility (which I highly appreciate), but also pushed me forward in the process and given clear feedback on good and bad ideas. I would also like to express my gratitude to Roger Sørheim, who during the whole process has been a valuable sparring partner, co-author, source of inspiration and friend. Sigmund Waagø deserves special mention, as he was the one dragging me into the academic world back in 2007 as a project manager for his entrepreneurship programs. Sigmund, I have enjoyed our conversations over the years, and thank you for your enthusiasm for technology-based entrepreneurship. Arild Aspelund is another important source of inspiration. Although we have not done research together, I sincerely hope that within a couple of years our coffee discussions can materialize into something like "Michelin's guide to the restaurant galaxy: A very, very in-depth study".

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As a Ph.D. student, I have been a part of CenSES – Centre for Sustainable Energy Studies. In addition to finance this Ph.D. (which includes four months as a guest researcher at the TU Berlin), CenSES has created a meeting space for interdisciplinary research on renewable energy. This has been valuable since it has given me a chance to gain insight on other perspectives and disciplines within renewable energy research and technology development. In addition, I would like to thank all the firms and individuals who took their time to participate in the studies and share their experiences and insights.

Out of the office, I have a fantastic supportive family and great friends who, besides asking repeatedly annoying questions about the thesis, means the world to me. You know who you are.

The final, and biggest, thank you goes to my lovely Carina. You have been supportive and patient since I started, and together with our fabulous boys, Sigurd and Erik, you have done your best to keep my mind off the doctoral thesis. That has also been very important – thank you!

Øyvind Bjørgum
Trondheim, February 2016

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Part I: The main report

1 Introduction and scope

This thesis focuses on how new, resource-constrained firms can be central in the development of a complex and technology-based emerging industry. To do this, the thesis studies how new firms interact with potential suppliers, investors and public agencies to acquire necessary resources and overcome technological, financial and organizational challenges towards commercializing their novel technologies.

Emerging industries are industries in the early stages of development (Low & Abrahamson, 1997). Because new industries may have a large economic impact on the success of firms and regions, it is important to understand the role of relevant stakeholders such as investors, existing firms and public organizations and how these interact. New knowledge in this area is especially important for policy makers as all new complex industries typically need public involvement in the emerging phase of the industry (Mazzucato, 2013a). Research on emerging industries remains relatively neglected (Forbes & Kirsch, 2011), however, and the existing research is scattered across different fields of scholarship such as strategy (e.g. Mitchell, 1989), entrepreneurship (e.g. Duchesneau & Gartner, 1990) and industrial economics (e.g. Klepper & Graddy, 1990).

Several industries, such as the 'dotcom'-firms in the mid-1990s or the many biotechnology start-ups in the 1980s (Hopkins, Crane, Nightingale, & Baden-Fuller, 2013), have been dominated by small firms during their earliest stages (Dinlersoz & MacDonald, 2009). This is understandable for industries in which new firms can expect to make commercial sales within some years, but it is less understandable for industries in which technology development is sufficiently complex and uncertain that at least 5–10 years are expected to pass before a commercial breakthrough. In emerging industries, especially those based on novel technologies for which no dominant design has been determined (Abernathy & Utterback, 1978; Anderson & Tushman, 1990), it is more difficult to understand why small and new firms are driving technology development, and the industries themselves, forward. In such extreme contexts, new firms based on novel technologies in emerging industries "must endure a *trifecta of burdens*: the firm's own liability of newness, the industry's lack of legitimacy and cohesive structure, and the technology's inherent uncertainty" (Woolley, 2014, p.722). Research within this field—new firms developing new technology in new industries—is lacking (Forbes & Kirsch, 2011; Woolley, 2014).

The industrial context of this thesis is the marine energy industry, which comprises firms developing devices to harness energy from ocean waves and tides. This is an extremely resource-demanding industry with long and expensive technology development processes; the first commercial energy parks are expected to begin operating around 2018–2020. Earlier studies have shown the technological barriers towards commercialization (Magagna & Uihlein, 2015), the difficulty of attracting private capital (Leete, Xu, & Wheeler, 2013) and that new independent firms and university spin-offs have dominated the industry in its earliest stages (Løvdal & Aspelund, 2011).

The background of this thesis is the author's interest in technology-based entrepreneurship, the commercialization of renewable energy and the huge challenges faced by firms in the emerging marine energy industry. Moreover, the fact that small start-ups dominate this complex and pre-commercial industry have inspired research into how this was possible and what the road towards commercialization will look like. Thus, the overarching research question of this thesis was formed:

How can new firms develop and commercialize novel and resource-demanding technologies in a complex emerging industry?

In an attempt to answer this question, four research papers were developed using different theoretical frameworks to investigate various aspects of the topic. Overall, the thesis makes several empirical and theoretical contributions to our understanding of the context of an emerging industry's early stages, which are empirically understudied (Forbes & Kirsch, 2011; Gustafsson, Jääskeläinen, Maula, & Uotila, 2015).

Internationalization to access critical resources

The first paper addresses how new firms access resources through internationalization and addresses two research questions:

- *What is the extent and scope of international funding and technology partnership among firms in the pre-sale phase in the marine energy industry?*
- *Why and how do such firms engage in international activities?*

The paper explores the extent of internationalization among Norwegian start-ups in the emerging marine energy industry. It studies the international activities on the upstream side, especially how internationalization can affect access to critical resources, such as funding and technology competence. On a theoretical level, this study addresses earlier shortcomings in the literature on international new ventures (INVs) and born globals (BGs) by illustrating the relevance of upstream international activities and how this has been understudied in earlier studies and definitions of INVs/BGs.

The non-financial contributions of investors

The second paper contributes to the understanding of investors' involvement in new technology firms in the early stages of an emerging industry. It investigates how new firms in the marine energy industry experience collaboration with different types of investors and addresses two research questions:

- *What kind of contributions do different types of investors bring to the table besides funding?*
- *To what extent are the investors' post-investment contributions relevant for technology firms in a pre-commercial industry?*

This study illustrates the extent and value that investor contributions can have and how the non-financial contributions have, in many cases, had a critical impact on firms' success or continued survival. The paper builds on earlier frameworks for categorizing investors' value-added contributions (De Clercq, Fried, Lehtonen, & Sapienza, 2006; Large & Muegge, 2007; Politis, 2008) but adjusts these to the context of emerging industries. The focus on different types of investor contributions also makes it possible to explore what an attractive investor path in the context of an early-stage emerging industry might look like.

Configuration of a supply chain

The third paper addresses challenges and opportunities that new technology firms in emerging industries face when they organize their technology development and their manufacturing of components and devices. It addresses two research questions:

- *What components and products should the firm produce internally, and what should it buy in the market?*
- *What level of integration should the firm develop between itself and its suppliers?*

The study uses transaction cost economics (TCE) to analyse both the firms' decision to make or buy their devices and the strength of a focal firm's ties to its most important suppliers. The study proposes three supply chain configurations for new firms in emerging industries and discusses strengths and weaknesses of these. Furthermore, the study highlights how difficult it might be for focal firms to engage suppliers when operating in the early stages of an emerging industry, before any dominant technological design or technological standards have appeared.

The entry of large multinational companies

The fourth paper investigates the entry of five large multinational companies (MNCs) into the emerging tidal energy industry and addresses two research questions:

- *Why did the MNCs choose their specific entry mode?*
- *How did uncertainty affect the choice of entry mode into the emerging tidal energy industry?*

The paper studies the entry modes of the five MNCs and investigates especially how pre-entry resources related to technology expertise and uncertainty affect their entry mode strategy. The MNCs enter the industry through internal development, acquisition or minority investments in SMEs, and these entry modes are different when it comes to the MNCs' control of development and their flexibility for learning and adjusting their investment later. Furthermore, the paper distinguishes between exogenous and endogenous uncertainty; the first is related to the emerging industry while the latter is related to the relationship between the entering MNC and the SME.

The remainder of Part 1 is organized as follows: First, I will give a more specific introduction to the marine energy industry. Second, I will more thoroughly present the relevant theoretical frameworks which the four individual papers have used, and I will point to research gaps within the emerging industry literature that this thesis intends to address. Third, I will give a short presentation of the four research papers, which are fully included in Part 2 of the thesis. Then, I discuss methodological considerations. Following this, the discussion chapter will elaborate on how this thesis has answered the overarching research question and how the four individual papers relate to each other in the context of technology commercialization. Finally, I will discuss contributions and the implications of the thesis.

2 The marine energy industry

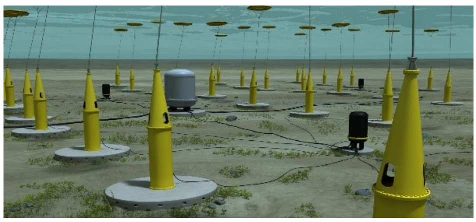
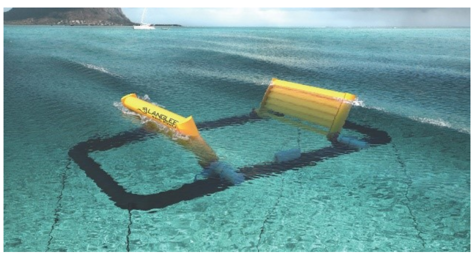
The study's context is the marine energy industry, also known as ocean energy, which comprises tidal and wave energy. Marine energy has experienced a considerable growth in interest in the last 15 years; however, it is still in a pre-commercial phase as no commercial power plants exist (Magagna & Uihlein, 2015) and a lack of design consensus among technology developers has led to a broad variety of technical solutions (MacGillivray et al., 2013). The huge benefit of marine energy is the great potential in large resources, combined with a placement of power plants under water or out in the sea, which lowers the risk of user conflicts (Sandgren, Hjort, Pimenta de Miranda, Hamarsland, & Ibenholt, 2007).

Although the wave and tidal energy industries have many similarities and challenges, they have become less alike, and they now face somewhat different challenges then they faced when the work on this thesis began. The main reason for this is that tidal energy has more or less settled on a main technological design and is, in general, closer to commercialization. In this section, I will first give an overview of the two technologies before introducing the current state of the marine energy industry.

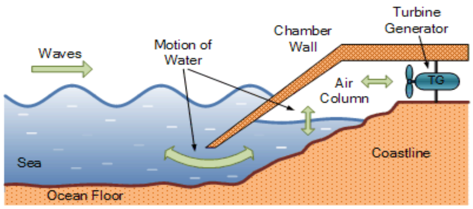
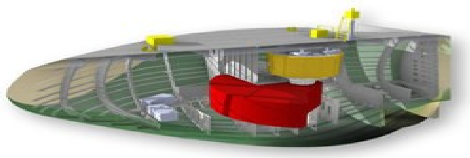
2.1 Wave energy

Waves offer a large source of energy that can be converted into electricity. The long-term potential for wave energy is very high, with worldwide natural potential, but the industry is facing tough technology challenges (MacGillivray et al., 2013; Magagna et al., 2014). Although ideas for wave energy conversion have been around for some time, with serious academic attention beginning in the early 1970s, extraction of wave energy at useful scales and costs has proved challenging. It is only recently, starting in the early 2000s, that many technology developers have started to produce full-scale prototypes and demonstrate the potential of the technology and industry (Mofor, Goldsmith, & Jones, 2014; Sandgren et al., 2007). Table 1 below shows and explains five of the most common types of wave energy converters (WECs) being developed.

Table 1: WEC Types

Device Type	Description	Illustration
Attenuator[1]	An Attenuator is a segmented device which lies parallel to the wave direction, effectively 'riding' the wave. The joints separating segments generate power by compressing hydraulic oil by means of two pistons.	
Point Absorber[2]	A Point Absorber wave energy converter consists of a floating buoy which is connected to a number of subsurface components. Energy is derived from the relative motion of the buoy to the subsurface components	
Oscillating Wave Surge Converter (OWSC)[3]	An Oscillating Wave Surge Converter is essentially a paddle which rotates around a fixed seabed mounting. The surge motion of the waves causes the paddle to rotate, which compresses water, driving an onshore turbine.	

[1] Picture from: https://www.facebook.com/PelamisWavePower
[2] Picture from: http://seabased.com
[3] Picture from: http://www.langleewavepower.com/media-centre

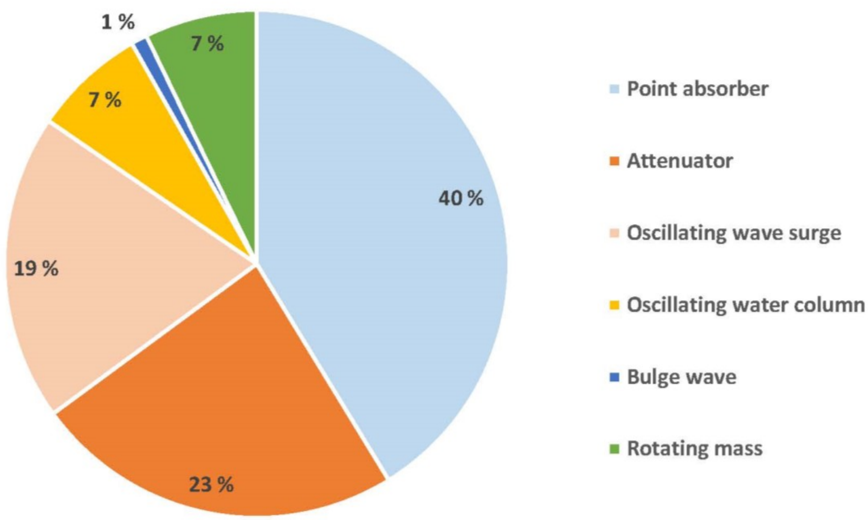
Oscillating Water Column (OWC)[4]	An Oscillating Water Column is a hollow concrete structure which houses a column of air, sealed at one end by the sea. As waves approach the device, the air column is compressed and forced through a bi-directional turbine.	
Rotating Mass[5]	Rotating Mass WECS use the motion of the waves to spin a rotating mass, creating mechanical energy.	

Although the first small array projects are currently being planned, as of December 2015, there are no utility-scale commercial WEC arrays operating anywhere in the world. At present, there are a number of grid-connected devices installed on test sites; these are pre-commercial prototypes of devices that are targeted for build-out into utility scale arrays, hopefully within the next decade. The most advanced device developers are now progressing beyond single-unit demonstration devices and are proceeding to array development and multi-megawatt projects, e.g. the Swedish company Seabased.

Much of the wave energy resource lies in deeper waters as wave energy levels increase predominantly with increasing distance from shore. The areas of deep water that are suitable for wave device deployment are significantly larger than the areas available for near-shore device deployment, so there is probably a larger market for deep water devices. However, this creates other challenges, such as water depths, distance to shore, grid infrastructure and generally harsher conditions (Mofor et al., 2014). As there is no dominant design within wave energy at the moment but rather a range of common types, no WEC is currently considered to be 'winning' or the 'best'. However, due to the range of different wave energy climates found around the world and the interest in different applications, such as offshore, nearshore and onshore, there may not be convergence on a single technology type in the wave energy sector (Mofor et al., 2014). Instead, different styles of devices may prove most suitable for different areas and uses. Figure 1 below shows the R&D investments in different types of WECs and illustrates the diversity in technologies being developed.

[4] Picture from: http://www.alternative-energy-tutorials.com/wave-energy/wave-energy-devices.html
[5] Picture of Wello: www.wello.eu

Figure 1: R&D spending on various wave energy technology types (Corsatea and Magagna, 2013)



The wave energy industry has not met the expected technology developments (Magagna & Uihlein, 2015), and it saw a major setback when one of the industry leaders, Pelamis, went bankrupt in 2015. Around half a dozen companies are currently leading the technology development but with no declared winner. A central technological problem is the need to improve wave energy converter technologies so that they can generate energy using average waves while surviving extreme weather conditions at lower costs (WEC, 2013).

2.2 Tidal energy

Within the tidal energy industry, this thesis focuses on turbines that are designed to convert the kinetic energy of tidal currents into electricity (i.e. not river currents, ocean currents or tidal barrage systems). The energy of the tides is highly predictable, but it is also geographically restricted as can be seen in Figure 2 below.

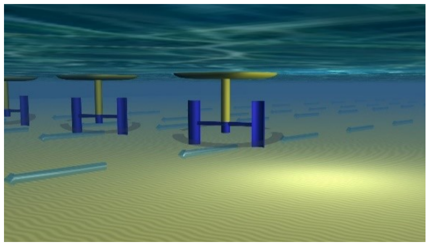
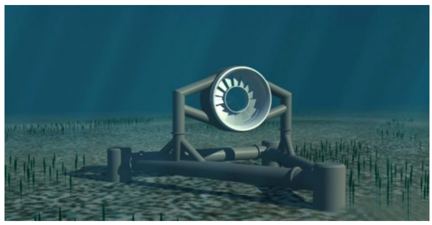
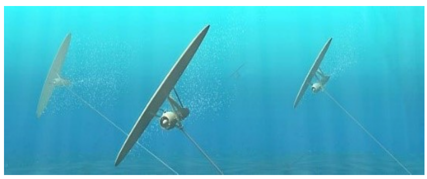
The tidal energy industry is most developed in the UK, but several prototypes are also being tested in Canadian and French waters (Magagna & Uihlein, 2015). In the short term, tidal energy most likely has larger potential than wave energy because the technology is more advanced. However, in the long term, the growth of tidal energy may be more restricted due to geographical constraints and limited natural potential.

Figure 2: Areas suitable for tidal power globally (Statkraft, 2006)

Tidal energy offers some advantages over other renewable energy resources, such as wind and wave. The fluid medium, sea water, is more than 800 times denser than air, so tidal energy offers a greater energy density than wind for a given turbine-rotor-swept area (Mofor et al., 2014). In essence, operation of a tidal device is synonymous to that of a wind turbine, but it operates within a different fluid medium. Thus, most tidal energy converter designs are representative of modified wind turbines since the principles of energy conversion are the same (Mofor et al., 2014). Although the wind industry has converged on the standard lift-based, three-bladed, horizontal-axis turbine predominantly seen throughout the world today, many designs were tried and tested in the early years of that industry (Jamieson, 2011). Table 2 below shows and explains four types of tidal turbine technologies.

Today, the most advanced tidal stream turbine developers are at a stage where they are testing and demonstrating individual prototypes in tidal streams representative of potential commercial sites. It is anticipated that commercial projects will operate in arrays of turbines as tidal farms, similar to the development of commercial utility-scale wind farms. The next stage for leading industry developers is to demonstrate their systems in small pilot arrays. The construction of the first pre-commercial arrays is under way, with operations planned to begin in 2016 by the Meygen project on the north coast of Scotland.

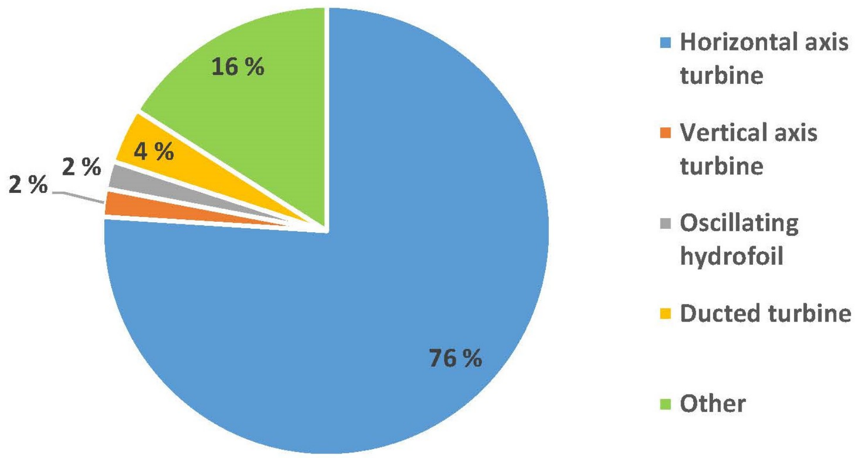
Table 2: Different types of tidal energy converters

Device type	Description	Illustration
Horizontal Axis Tidal Turbine (HATT)[6]	HATTs operate in a very similar manner to wind turbines. As the water flows over the blades, a perpendicular lift force is generated, causing the rotor to spin.	
Vertical Axis Tidal Turbine (VATT)[7]	VATTs are drag devices. As the flow reaches the blades, they are rotated by the force of the water.	
Enclosed Tips (Ducted)[8]	Enclosed tips tidal turbines utilise the venturi (narrowing and then expanding) geometry to create a low pressure area behind the turbine. This pressure differential drives the turbine.	
Tidal Kite[9]	Tidal Kites use a wing and turbine assembly tethered to a fixed point on the seabed. As water approaches the assembly, it creates a lift force, causing the wing and turbine to move through the water.	

Although there are several tidal energy designs being actively developed (as illustrated in Table 2 above), Figure 3 below shows that the tidal energy industry has experienced a far greater design convergence than the wave energy industry. Around 75% of the foremost tidal energy converter concepts have adopted a horizontal axis turbine similar to that of the wind industry (Magagna & Uihlein, 2015).

[6] Picture of AR1000 from: http://atlantisresourcesltd.com
[7] Picture from: www.aquaret.com
[8] Picture of Open Hydro from: http://www.openhydro.com
[9] Picture of Minesto's Deep Green from: www.minesto.com

Figure 3: R&D spending on various tidal energy technology types (Corsatea & Magagna, 2013)



2.3 Public policy

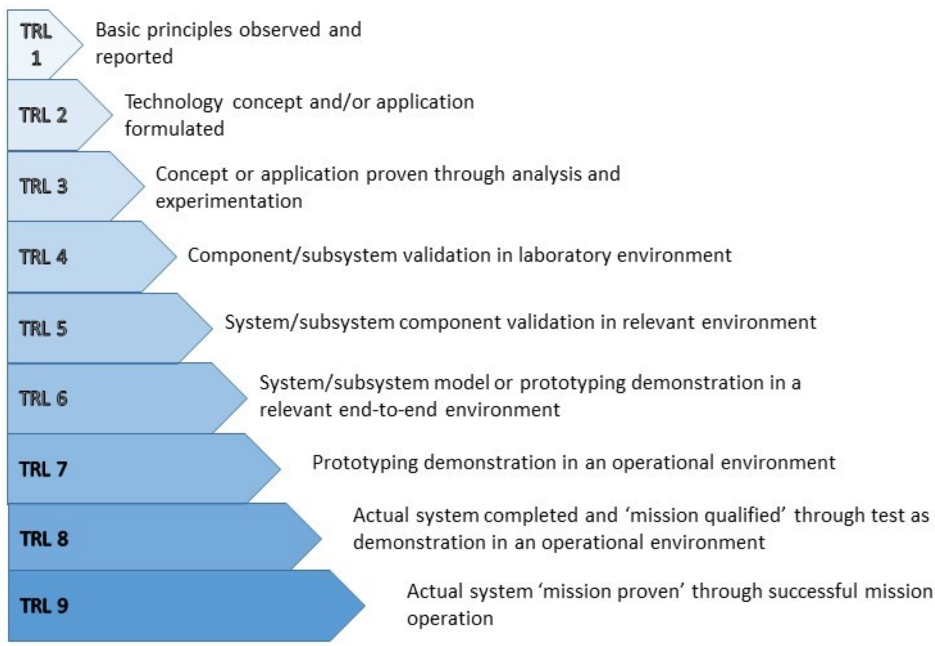
Although this thesis is mainly focusing on the bottlenecks of technology development and financing, an introduction to the industry cannot be made without touching upon the importance of public policy and frameworks. In fact, since it is new, the marine energy industry requires the simultaneous development of not only the method for generating energy but also of public support for technology development, financial market incentives, public consents, environmental legislation and surrounding infrastructure, such as storage and distribution of electricity. For instance, as regulatory bodies are in charge of both general regulations and support schemes for the marine energy industry, it is crucial for firms in the industry to develop good relations with these governmental actors. These regulatory bodies range from local authorities (e.g. the Scottish government) to international authorities (e.g. the European Commission), to other nations' local authorities. Furthermore, the competitiveness of new renewable energy sources is highly dependent on the end-market and the current policy framework. Since the market and the regulatory bodies set the energy prices and the CO2 prices, they will greatly affect whether marine energy technologies are financially viable or not. Even projects with low technology costs and otherwise favourable conditions may become unviable due to unfavourable policies or market conditions. The short-term marginal pricing of electricity makes capital-intensive investments risky unless other financial incentives are in place, such as feed-in tariffs (IEA, 2013). However, this thesis will only discuss policy when it is directly related to initiatives affecting the focal firms' technology development and funding.

In most of the world, marine energy is not a priority, and its supporting mechanisms are too weak to bring the technology towards commercialization. However, the UK is an important exception as that country's government is aiming to make marine energy a success story; the UK is by far the leading region in this respect (Krohn et al., 2013; OES, 2015; Renewable-UK, 2012). In addition to having excellent geographical conditions for both wave and tidal energy, the UK holds several advantages within this sector as it has a strong academic research and development capacity, a high concentration of technology development companies and the ability to exploit knowledge and skills in traditional maritime and offshore industries (Carbon-Trust, 2012). However, France and Canada have also secured strong support for infrastructure development and financial support systems for developers primarily within the tidal energy field (OES, 2015).

2.4 Technology development and costs

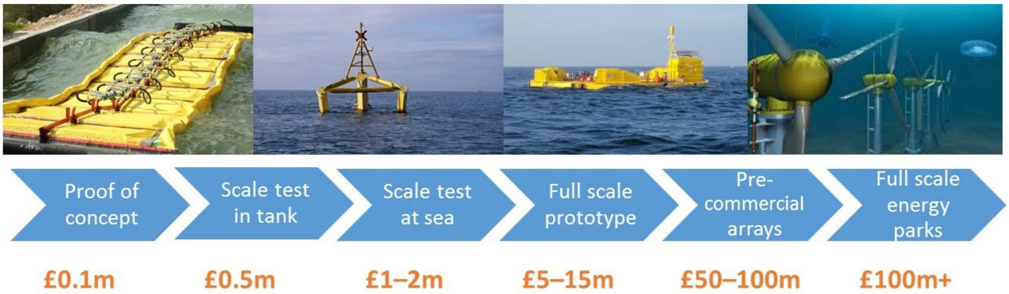
A common method for describing and categorizing the maturity of new technologies is the *Technology Readiness Level* (TRL) (Mankins, 1995). It was developed by NASA in the 80s and is widely used in the marine energy industry. Figure 4 illustrates the TRL in more details. A given technology is ready for commercial use at TRL 9.

Figure 4: Technology Readiness Levels—TRLs (Mankins, 1995)



However, in the marine energy industry, the road to TRL 9 is technologically challenging and capital intensive, which puts pressure on the technology developers to secure funding (IEA, 2013). As of December 2015, the leading technologies within the marine energy industry are at approximately TRLs 8–9, and most of these are within the tidal energy field. Furthermore, the high cost of developing technology from idea stage to commercial use in the marine energy field is illustrated by Figure 5 below.

Figure 5: Approximate development costs in the marine energy industry (Wyatt, 2014)[10]



2.5 Current status of the marine energy industry

As of February 2014, an internally generated DNV GL database had identified 176 different wave energy concepts and 82 different tidal turbine concepts (Mofor et al., 2014, pages 37-47). However, of these, only 36 of the wave energy developers and 25 of the tidal turbine developers had reached the stage of testing large devices and actively developing technology (Mofor et al., 2014). These companies were located across the globe but, as we can see in Table 3, around half of them were from the British Isles or the Nordic countries.

Table 3: Overview of advanced marine energy firms and their nationality

Region	UK and Ireland	Nordic countries	USA and Canada	Australia and New Zealand	Rest of the world
Tidal firms	34%	13%	14%	3%	36%
Wave firms	22%	26%	16%	16%	20%

The industry has, since its infancy, been led by university spin-offs and independent start-ups (Løvdal & Aspelund, 2011), and these companies still dominate the industry in terms of number of firms (Mofor et al., 2014). According to the database used in Table 3 above, a total of 84% (21 out of

[10] Photos from left: Tank test of Waveline (www.swel.eu), Evopod (www.oceanflowenergy.com), the Bolt/Fred Olsen (www.fabtest.com) and an array of HA1000 (www.hammerfeststrom.com)

25) of the tidal firms were independent start-ups while four were internally developed by large firms. In addition, six of these independent start-ups had since been acquired or controlled by larger firms that had entered the tidal industry. Among the wave energy firms, 34 of 36 firms are university spin-offs and independent start-ups; only two were developed through existing organizations. And although several large firms have made small investments in the wave energy industry, only one or two have been acquired by larger firms.

The entry of large MNCs into the tidal energy industry, primarily through investments or acquisitions of already-existing firms (Renewable-UK, 2012), has had several implications for the tidal energy industry. First, the MNCs have all chosen to invest in the same type of technology, the horizontal axis turbine, which has made it extremely difficult for firms developing other designs to fund full-scale tests of their technology (ICOE, 2014). Thus, the entry of MNCs has more or less made the horizontal axis turbine the 'dominant design' in the industry. Additionally, the technology understanding and large investments of MNCs into the horizontal axis turbine design might be an important reason that tidal technology has progressed further towards commercialization than wave technology (ORE-Catapult, 2014).

Second, the entry of MNCs has strengthened the industrialization of the technologies as these firms have implemented manufacturing expertise and global value chains. In addition, their entry has affected the underdeveloped supply chain (Magagna et al., 2014) of the tidal energy industry. MNCs have a global presence, and there is a wide belief that their global supply chains and manufacturing facilities can bring costs down (ORE-Catapult, 2014).

Third, many previous marine energy projects have failed to deliver their objectives and, thereby, have reduced the credibility and damaged the reputation of the industry (Krohn et al., 2013). This has made many investors sceptical of the industry (Leete et al., 2013). However, the entry of MNCs into the tidal energy industry has increased its credibility (ICOE, 2014; Renewable-UK, 2012). MNCs' ability to provide warranties for their technology's performance combined with their engineering expertise has created confidence in tidal technology (ORE-Catapult, 2014) from customers and public funding sources.

3 Theoretical perspectives used in the dissertation

3.1 Theoretical scoping/perspectives

The objective of this thesis is to investigate the role of new firms and how they interact with other stakeholders when developing novel technology in a complex and capital-intensive emerging industry. The individual papers use different theoretical frameworks depending on the research questions, but the context of them all is the emerging marine energy industry.

3.2 Emerging industries

Emerging industries are industries in the early stages of development (Forbes & Kirsch, 2011; Low & Abrahamson, 1997), which is a dynamic stage where technology, products and industry participants are continuously changing (Phaal, O'Sullivan, Routley, Ford, & Probert, 2011). Emerging industries have been described as industries in a 'formative period' (e.g. Audretsch & Feldman, 1996), and have been studied under different labels, such as 'embryonic' (Klepper, 1997), 'introductory' (Mazzucato, 2002) and 'nascent' (Santos & Eisenhardt, 2009). The research on emerging industries is dispersed across various research fields, such as economics, marketing, socio-technical systems, industrial economics and entrepreneurship, which has led to a scattered and dispersed literature (Forbes & Kirsch, 2011; Gustafsson et al., 2015; Phaal et al., 2011).

The recent reviews by Forbes and Kirsch (2011) and Gustafsson et al. (2015) show an increasing interest in the emergence of new industries, which has been a phenomenon relatively neglected by researchers. Forbes and Kirsch (2011) address several theoretical and methodological problems in the study of emerging industries, and they generally advocate for the use of more varied methods, especially qualitative methods and historical data, and for researchers to do more cross-disciplinary research. Gustafsson et al. (2015) highlight that their work is the first systematic review of the emergence of industries and that it is an important step towards an integrative theoretical framework. Both these reviews find that earlier studies on emerging industries have studied different stages of those industries without necessarily making a distinction between the stages. Based on their review of the emerging industry literature, Gustafsson et al. (2015) separate emerging industries into three stages: (1) *the initial stage* is an embryonic stage during which the existing industrial order or technological system is challenged but before a clear industrial structure has been developed. In (2) *the co-evolutionary stage,* the technological progress co-develops with the emergence of financial institutions, such as venture capital (VC) funding (Avnimelech & Teubal, 2006), and the central role of public institutions (Gustafsson et al., 2015). (3) *The growth stage* is when commercial sales take off; this leads to sustainable industrial growth.

The focus of this thesis is on the *co-evolutionary stage*, also referred to as *the emergent period* (Forbes & Kirsch, 2011). This stage takes place after an industry has been formed and before a dominant technological design (Abernathy & Utterback, 1978; Utterback & Abernathy, 1975) has emerged. This stage is characterized by intensive competition between several different technologies (Kapoor & Furr, 2015), a lack of well-established product and marketing standards (Low & Abrahamson, 1997) and high uncertainty for both investors and entrepreneurs due to the variety of technologies present (Von Burg & Kenney, 2000).

Emerging industries also differ greatly in terms of complexity. For example, the road towards commercialization, the number of stakeholders and degree of public involvement in different emerging industries, such as the business coaching industry (Clegg, Rhodes, Kornberger, & Stilin, 2005) and the solar photovoltaic industry (Kapoor & Furr, 2015) are very different. In fact, the length of the time that an industry remains in the emerging stage is found to vary across industries from two to around 50 years (Klepper & Graddy, 1990). Funk (2010) measures industry complexity in terms of the number of subsystems or processes needed in the initial products and argues that complex systems usually require more decisions to be made, greater public sector involvement and more R&D than less complex industries. A complex industry requires a critical mass of users or complementary products for commercialization to occur, and industries involving such complex systems face additional challenges not faced by those with simpler products (Funk, 2010). These additional challenges require more government involvement; examples of complex industries are wind energy, nuclear power, biotechnology and semiconductors, all of which have had heavy public involvement in their early stages (Funk, 2010; Mazzucato, 2013a). Furthermore, in emerging industries where government involvement and decision-making is central, uncertainties regarding the policy direction and size of subsidies can increase the difficulty of communicating viable business proposals to potential investors (Von Burg & Kenney, 2000).

Firms enter emerging industries either as new firms or through diversification from other industries. As start-ups are important sources of innovative new ideas and technologies (Giarratana, 2004; Hill & Rothaermel, 2003), some emerging industries arise primarily through the entry of new, independent firms, such as the many 'dotcom'-firms in the mid-1990s or the many biotechnology start-ups in the 1980s (Hopkins et al., 2013). In some cases, larger firms from adjacent or other industries enter as the industry moves closer to commercialization; such has occurred in the emerging and capital-intensive biotechnology industry (Hopkins et al., 2013). Although emerging industries can be dominated by large firms, such as the disk array industry in the 80s and 90s (McKendrick, Jaffee, Carroll, & Khessina, 2003), studies have found that new firms are more common than larger firms in emerging industries, but also that larger firms are, on average, more successful (Dinlersoz & MacDonald, 2009).

3.3 Gaps in the literature on emerging industries

Recent reviews by Gustafsson et al. (2015) and Forbes and Kirsch (2011) indicate the need for more research on emerging industries. Specifically, there has been limited research on interactions and interdependencies between sub-processes, for instance such as how the lack of technological bases influences the development of an end-market (Gustafsson et al., 2015). In addition, there is a need for studies which analyse how various types of organizational actors, such as innovators, customers, financiers and policy makers, interact (Forbes & Kirsch, 2011; Woolley, 2014), especially in the earliest stages of industry emergence (Gustafsson et al., 2015). Furthermore, according to Gustafsson et al. (2015), there have been surprisingly few studies of the emergence of an industry in more than one geographical setting.

Although earlier research has examined entrepreneurship using new technologies and entrepreneurship within emerging industries, few studies have brought these three domains together, and there exists no theoretical framework to understand nascent technology entrepreneurship in new industries (Woolley, 2014). How new firms operate and interact with other stakeholders to be able to develop novel and complex technology, in the challenging context of the early stages of an emerging industry, is the core of this thesis.

3.4 New firms with new technologies in new industries

New technology firms are important participants in the development of new industries (Dinlersoz & MacDonald, 2009) because of their introduction of new, innovative technology. However, with limited internal resources (e.g. Brush, Greene, & Hart, 2001), new firms require input, such as funding, industry-specific expertise, contacts with potential customers, technology competence, foreign market knowledge or expertise in business administration, to bring their technology towards commercialization. This is extra challenging in new industries wherein firms typically will need to search and reach out across industry borders to acquire the necessary resources and competences (Doz, Santos, & Williamson, 2001). Furthermore, firms in early-stage emerging industries do not have the same socio-political legitimacy as firms operating within existing industries; those in the latter group "do not have to build trust within a vacuum" (Aldrich & Fiol, 1994, p. 650). In the early stages of an emerging industry, there is typically low legitimacy because of limited standards, limited numbers of renowned players, and high uncertainty in the market and the technology makes the situation even harder. In such contexts, new firms in emerging industries must be prepared to face extremely sceptical customers, investors, suppliers and other stakeholders, who are hard to convince without a track record (Aldrich & Fiol, 1994; Zimmerman & Zeitz, 2002).

Thus, new technology firms in emerging industries must endure a *trifecta of burdens* consisting of their own liability of newness, the industry's lack of legitimacy and structure and the technology's inherent uncertainty (Woolley, 2014). The following section will introduce theoretical frameworks used in the individual papers, which help explain how new firms can overcome the *trifecta of burdens* towards commercializing their technology.

3.5 International new ventures (INVs)

INVs are firms that undertake international activity within their first few years of operation; a INV is defined in the seminal article by Oviatt and McDougall (1994, p.49), as "a business organization that, from inception, seeks to derive significant competitive advantages from the use of resources and the sales of outputs in multiple countries". Before this article, international business research was mostly focused on large companies, which typically had a slow and incremental internationalization process (Johanson & Vahlne, 1977). Oviatt and McDougall (1994) showed how many new firms did not fit into the existing internationalization models as these firms entered international markets from inception. Later research on INVs has shown how new firms can have international operations without the extensive resource base of larger firms because they typically use less resource-demanding strategies, such as partnerships and networking (Gabrielsson & Manek Kirpalani, 2004). Since new firms are typically resource-constrained (Brush et al., 2001; Phillips McDougall, Shane, & Oviatt, 1994), the ability to cross national borders could be very important in emerging industries as this might increase the number of potential partners and funders for the firm.

In complex emerging industries, the technology development process is typically long; examples include the biotechnology (Hewerdine & Welch, 2013) and renewable energy industries (Mazzucato, 2013a). Then it may be of vital importance to gain access to international funding sources and technology competence through interactions with international R&D partners or suppliers. The INV perspective is then useful in studying and explaining why and how new firms can use internationalization to access critical resources.

3.6 Entrepreneurial finance

Entrepreneurial finance literature addresses the various benefits and costs associated with alternative sources of financing for new firms (Denis, 2004). Central questions in the entrepreneurial finance literature include the amount of capital required and from whom a firm raises it. Start-ups developing technology typically need external capital until they generate an adequate cash flow from sales. This capital usually comes from public grants or from private equity sources, such as venture capital funds (VCs), business angels (BAs), and corporate investors. VCs refer to limited partnerships in which the managing partners invest on behalf of the limited partners, BAs refer to high net worth individuals investing their own private money and corporate investors are larger firms investing on behalf of their shareholders for strategic or financial reason (De Clercq et al., 2006; Denis, 2004).

For new technology firms in the early stages of emerging industries, attracting investors is typically hard as there is high uncertainty and few track records (Aldrich & Fiol, 1994), and the demand for relevant networks and technology competence is high. Then, the additional contributions to capital which an investor brings to the table can be important. Within the entrepreneurial finance literature, there is a wide body of research on the non-financial contributions or the value-added of, especially, VCs (e.g. Busenitz, Fiet, & Moesel, 2004; Gorman & Sahlman, 1989; Sapienza, 1992) but also BAs (e.g. Madill, Haines, & Riding, 2005; Politis, 2008; Sætre, 2003) and corporate capital ventures (CVCs) (e.g. Gompers & Lerner, 2000; Maula, 2001). Earlier findings have displayed different non-financial contributions, such as help obtaining additional funding (Sørheim, 2005), business competence and networks (Berg-Utby, Sørheim, & Widding, 2007; Mason, 2007), legitimacy (De Clercq et al., 2006; Large & Muegge, 2007) and manufacturing and technology expertise (Maula, Autio, & Murray, 2005).

Thus, earlier research has displayed how investors could have important roles for new technology firms in emerging industries. More precisely, investors can strengthen the technology development of the focal firm, help to professionalize the organization, provide networks or attract new investors and technology partners and help to increase the credibility of both the firm and the industry.

3.7 Transaction cost economics (TCE)

The central question in TCE is why firms internalize transactions that otherwise could have been conducted in the marketplace (Coase, 1937). TCE provides arguments for when to organise economic activities in hierarchies (make) and when to organise them in markets (buy) (Williamson, 1975; Williamson, 1981; Williamson, 1985). Transaction costs include the costs of searching for vendors, administering the transaction, risk hedging, control and follow-up. In addition to transaction costs, companies also face production costs, which are the actual costs of producing the product or service. The decision to organise a firm's transactions in hierarchies or markets is then based on a comparison of the total costs of the two alternatives. Furthermore, there are three dimensions that particularly impact the transaction costs: transaction frequency, transaction uncertainty and asset specificity. Of these dimensions, *asset specificity* is regarded most critical for describing transactions (e.g. David & Han, 2004; Shelanski & Klein, 1995; Williamson, 1985). It refers to the assets that are directly related to a particular transaction, and high asset specificity means that an asset has little value outside a specific business relationship. Asset specificity can take the form of site specificity (closeness between seller and buyer), physical asset specificity (systems have to be adapted to facilitate exchange), or human asset specificity (transactions demand special skills).

TCE has been criticised for being under-socialised, mechanistic and, specifically, for underestimating the value of interpersonal relationships. TCE has, therefore, been expanded through an understanding of the strength of the ties in buyer-supplier relationships (Grover & Malhotra, 2003; Williamson, 1991), which allows differentiation between arms-length relationships (weak ties) and alliances (strong ties) in these relationships (Geyskens, Steenkamp, & Kumar, 2006; Hoyt & Huq, 2000; Williamson, 1991).

For a new firm in an emerging industry that is developing novel technology, the choice of what it should buy in the marketplace and what it should make internally is central. In addition, when developing novel technology, there can be limitations to what a new firm *can* buy in the marketplace; these limitations will affect its organization of technology development. Furthermore, both the strength of ties to suppliers and the ability to engage the right suppliers and partners in technology development and testing have important implications in the technology development process in an emerging industry, where technology competence and legitimacy could be critical inputs.

3.8 Entry modes and uncertainty

When an emerging industry moves closer to commercialization, it becomes interesting for more large firms from adjacent industries to enter the industry. However, the decision to enter an emerging industry, such as the marine energy industry, must be carefully considered as there are many uncertainties related to market, technologies, policy frameworks and companies. Earlier studies on firms' choice of entry mode (e.g. Billitteri, Nigro, & Perrone, 2013; Folta, 1998; van de Vrande, Vanhaverbeke, & Duysters, 2009) have showed that firms choose between entry modes giving *flexibility* or *control*. The importance of having flexibility when entering an emerging industry can be understood by applying a real options (RO) perspective, while the importance of *control* can be understood by applying a TCE perspective.

ROs are sequential and irreversible investments made under conditions of uncertainty. The options provide flexibility by generating future decision rights (Vanhaverbeke, Van de Vrande, & Chesbrough, 2008), and this flexibility is more valuable the higher the level of uncertainty. According to RO theory, when facing high levels of uncertainty firms should make small initial investments in order to gradually learn about the industry (Janney & Dess, 2004), decrease the uncertainties and have the opportunity to make follow-up investments (Folta, 1998). This will allow firms to cope with unforeseen problems and reverse investments with a low degree of financial commitment. Examples of flexible entry modes could be non-equity partnerships or minority investments.

TCE, as presented in Chapter 3.7 above, generally assumes that simple market contracts provide a more efficient, or lower cost, mechanism for managing economic exchanges than hierarchical organizations. However, because of bounded rationality, most complex contracts are incomplete and, in such cases, the firms should internalize transactions (Leiblein, 2003). When entering an emerging industry, the choice of entry mode will be affected by uncertainties related to market characteristics, technological uncertainty or complexity in the economic exchange, which all raise the potential for opportunistic behaviour and the expected cost of writing and enforcing relations (Williamson, 1985). According to Leiblein (2003), market failure is particularly likely in situations where high levels of asset specificity and uncertainty are present; in such situations, TCE reasoning suggests that entering firms choose entry modes that give control. Examples of entry modes giving control are internal development and acquisitions.

3.9 Summary of theoretical perspectives used in the thesis

The previous sections have presented research on emerging industries and the limited attention to new firms developing novel technology in the early stages of an emerging industry. Furthermore, to answer the overall research question (i.e. 'How can new firms develop and commercialize novel and resource-demanding technologies in a complex emerging industry?'), this thesis explores how new firms access external resources and organize their activities towards commercialization of their technology. As shown in Table 4 below, the theoretical frameworks of INVs, entrepreneurial finance, TCE and RO, are helpful in this.

Table 4: Overview of industry characteristics and relevant theoretical frameworks

The emerging marine industry characteristics	Implication(s)	Relevant theoretical framework(s)
Industry is dominated by resource-constrained new firms	Firms need to access external resources	- International new ventures - Entrepreneurial finance
Highly international industry, but only UK has the whole value chain nationally	Firms typically need to venture abroad to find customers, suppliers, investors or partners as possibilities could be limited in home market.	- International new ventures

Technology development process is long and expensive	Firms need external funding	- Entrepreneurial finance
Technology is typically complex, large and operates in rough environment	Firms need to find technology suppliers/partners and need to configure supply chain.	- TCE
Large firms are entering the industry through various entry modes	Large firms need to find best technologies and entry modes in highly uncertain environments	- RO theory - TCE

4 The four research papers and the main findings

This chapter gives a short summary of the four papers included in this thesis. All four papers use empirical data from qualitative cases related to new firms in the marine energy industry developing novel technology in an emerging industry. The four papers address different aspects of the commercialization process and how new firms collaborate and involve different actors. Table 5 presents an overview of the research papers.

Table 5: Papers included in this thesis

Paper	Title	Author(s)	Publication status
1	New ventures in an emerging industry: access to and use of international resources	Ø. Bjørgum Ø. Moen T. K. Madsen	Published in *International Journal of Entrepreneurship and Small Business, 20*(2), 233-253, 2013
2	The funding of new technology firms in a pre-commercial industry—the role of smart capital	Ø. Bjørgum R. Sørheim	Published in *Technology Analysis & Strategic Management*, *27*(3), 249-266, 2015
3	Configuration of supply chains in emerging industries: a multiple-case study in the wave-and-tidal energy industry	Ø. Bjørgum T. Netland	Accepted for publication in *International Journal of Manufacturing Technology and Management*, Special issue on **'Supply chain evolution in emerging industries'** *(forthcoming 2016)*
4	The entry of MNCs into an emerging industry: the choice of entry mode and the role of uncertainty	Ø. Bjørgum	Submitted to an international peer-reviewed journal

4.1 Research Paper 1: 'New ventures in an emerging industry: access to and use of international resources'

Research questions:

- What is the extent and scope of international funding and technology partnership among firms in the pre-sale phase in the marine energy industry?
- Why and how do such firms engage in international activities?

Background:

This study explores the international activities of new ventures in the early stages of an emerging industry, and it is inspired by the earlier work of Løvdal (2011) on internationalization in the offshore renewable energy industry. In addition to digging deeper into the extent of internationalization among a major part of the Norwegian marine energy industry, the study also gave a deeper understanding of the major challenges facing new firms in the industry and inspired further studies.

Method:

The study covers eight Norwegian marine energy firms and uses a multiple-case design (Eisenhardt & Graebner, 2007). The primary sources are eight interviews with senior managers in the companies while the secondary sources are national and international industry reports, industry conferences in Norway and Scotland, company and industry websites, news articles and interviews with representatives from authorities and industry organisations. The interviews were conducted in late autumn 2011 and were based on a semi-structured questionnaire addressing themes such as the basic product concept and company background, technology development, partnerships and collaboration, funding, international activities and policy frameworks. We identified 16 Norwegian wave and tidal energy companies, all of which were contacted and asked to participate in the study. Four of the firms did not meet our selection criteria as we only were interested in active firms with full-time employees developing wave or tidal energy technology. Four firms did not respond to our inquiries or did not wish to participate. We transcribed all of the interviews and conducted a within-case analysis of each company, after which we produced a three- to five-page summary of each company based on the interviews and additional information from external sources. These case summaries were sent to the interviewees for approval and to ensure construct validity. We then performed a cross-case analysis (Eisenhardt, 1989) by selecting categories such as funding sources and technology partnerships that were relevant for our research questions and by designing tables to analyse and identify common and differential factors.

Key findings:

In this paper, we provide insights on how new firms in emerging industries can use internationalization to access scarce resources, such as funding and technology competence, to further develop their technology towards commercialization. The emerging industry strengthens the need to internationalize because of limited interest from public and private organizations in Norway (push) and attractive public funding schemes and more interested collaborating firms and investors abroad (pull).

We find large differences among the case companies' international activities and divide them into three groups: (1) *Technology- and funding-driven internationalizers,* (2) *Market-driven* internationalizers, and (3) those with *no or limited internationalization.* The motivations and actual forms of international activities of the case companies are, thus, quite diverse, but the overall findings suggest that international engagement has been beneficial for case companies in Groups 1 and 2 as these were most successful in attracting external funding and technology partners. Furthermore, it seems that technology development arrangements are connected to funding. For example, companies establish partnerships with international firms to be in a better position to receive public grants for technology development and pilot testing, or technology partners receive shares or invest their own equity into the venture. Moreover, the willingness to move all or some of their operations to another country, to have better funding possibilities or partnerships, is striking.

This paper also discusses the implications of our findings in regard of common definitions within the international entrepreneurship literature on BGs and INVs. Because earlier studies of INVs/BGs have only focused on international activities on the sales side, it is likely that these have neglected to include firms with early internationalization activities upstream. Our study, therefore, strongly supports the inclusion of aspects other than sales when categorising firms according to their degree of internationalization. The mindset of these firms' management is clearly international, and their early international activities will definitely provide a foundation for subsequent international sales of their solutions. To understand their later international activities, it is important to understand their initial internationalization process. We therefore suggest a modification of Oviatt and McDougall's (1994) definition of an INV, which includes upstream activities and would be more useful when conducting research on INVs and BGs.

Finally, this study inspired me to do further studies on firms in the emerging marine energy industry, especially on the role of different types of investors (Paper 2) and how firms organize their technology development and manufacturing and assembly of components (Paper 3).

4.2 Research Paper 2: 'The funding of technology firms in an emerging industry—the role of smart capital'

Research questions:

- What kind of contributions do different types of investors bring to the table besides funding?
- To what extent are the investors' post-investment contributions relevant for technology firms in a pre-commercial industry?

Background:

When writing Paper 1, it was interesting to see how many different types of investors those case companies had. It also appeared as the different owners had different involvement and contributions. These ideas led to this paper, which is designed to provide insight on the non-financial value-added from different types of investors for new technology firms in the early stages of an emerging industry. Most new technology-based firms face a challenge in obtaining enough funding to commercialize their products, and for firms in capital-intensive emerging industries with no standards, no supply chain and no commercial products, this challenge is even greater.

Method:

The study is a multiple-case study of six marine energy firms from the Nordic countries. The primary sources are transcribed interviews with senior managers or founders of the firms. The interviews focused on ownership structure, the pre-investment phase, investor engagement and contributions, investor relationship, future financing and the technology development process. Secondary sources include the case companies' websites, news articles, press releases, industry websites, industry reports, international industry-specific conferences (the US, Scandinavia and Scotland), publicly available consent applications and investor websites. All the case firms come from the Nordic countries, and they all have a relatively rich history of private investments and experience with different investor types. By combining the different sources of information, an in-depth description of the funding process was obtained. In the analysis, we designed tables related to the research questions and performed a cross-case analysis by identifying common and differential factors between the individual cases related to the research questions.

Key findings:

The six case companies had a wide variety in terms of numbers of investors, types of investors and amounts of value-added from investors. A majority of the case companies had investors within all the investor categories: BAs, VCs and larger corporations (CVCs). The firm with the most investors had around 100 small, private individuals plus VC and some funding from a larger corporation while another had just three BAs as investors. Furthermore, our results show that the amount of value-added is high and that the different types of investors' contributions clearly differ within the categories of 'Business development', 'Technology development', 'Investor's outreach' and 'Legitimacy'.

Our findings indicate that, for technology developing ventures in an emerging industry, the most important contributions occur when investors help attract new resources or strengthen existing resources. We find that CVCs make important contributions within technology development and that the major benefit of having a CVC investor is the legitimacy it adds to the young firm. This legitimacy effect is, of course, important for any start-up firm in a capital-intensive industry, but it will be of outmost importance in a capital-intensive pre-commercial industry. The legitimacy effect appears to be of vital importance to firms in emerging industries facing true uncertainty with regard to both technology development and the maturity of the market.

Our study also suggests that companies in this pre-commercial industry are too focused on attracting VC investors and that established firms and CVCs may have a more relevant role than traditional VCs for new firms in emerging industries. This is because of VCs' goal of exiting their investment within typically three to five years and accelerated development plans, which are too short term for this type of industry stage. The fact that all of the case companies have one or more BAs among the investors and that four of the six case companies had BAs as their first investor, shows how important BAs are as providers of capital in the critical first phase, even in a pre-commercial industry with long time horizons.

4.3 Research Paper 3: 'Configuration of supply chains in emerging industries: a multiple-case study in the wave-and-tidal energy industry'

Research questions:

- What components and product should the firm produce internally, and what should it buy in the market?
- What level of integration should the firm develop between itself and its suppliers?

Background:

The exploratory case study resulting in Paper 1 also spurred an interest into how new firms in the marine energy industry organize their technology development and production/assembly of components and devices. First of all, very few start-ups are able to possess or build up the capability needed to develop and commercialize such complex technology by themselves; therefore, they must be able to find and engage technology partners and suppliers of components. In the early stages of an emerging industry where there are no dominant designs and no industry standards, a supply chain does not exist. This forces firms to identify and engage suppliers from other or related industries. The paper uses TCE and is limited to the analysis of two classic supply chain design parameters: the make versus buy decision, and the weak versus strong ties of supply chain relationships.

Method:

We use a multiple-case study to explore supply chain configuration issues in the emerging marine energy industry. All the case companies had experience with making prototypes and cooperating with suppliers. The chosen cases were seven small, young firms located in Denmark, Finland, Norway, Sweden and the UK. The primary data sources are interviews with senior managers while the secondary data sources consist of publicly available information, e.g. websites, news, press releases, industry reports, and international industry-specific conferences. All interviews were transcribed and manually coded. We analyse the seven individual cases before conducting a cross-case analysis related to supply chain configuration as recommended by Miles and Huberman (1994) and Eisenhardt (1989).

Key findings:

The study confirms that it is challenging to strategically configure supply chains in the early stages of emerging industries. We propose three models that can be useful in a strategic discussion of what type of supply chain configuration firms should aim to build. These three models are based on the seven case companies' decisions to buy or make their final products and on whether they have weak or strong ties with suppliers. Our three models of supply chain configuration are 'the Market Model', 'the Ally Model' and 'the Maker Model'. The Market Model is based on arms-length relationships with suppliers and keeps alternatives open, but it lacks the benefits of cooperative technology development and legitimacy-building partnerships. In the Ally Model, focal firms have a close relationship with suppliers, allowing the firms to access the suppliers' technological competence. Furthermore, close partnerships with renowned suppliers may also give the focal firms a legitimacy effect, which will strengthen their credibility towards external stakeholders, such as government agencies, investors and other firms. This legitimacy effect is especially important in the early stages of emerging industries, when the lack of a track record, of dominant technology and of standards creates high uncertainty. In the Maker Model, the focal firms manufacture the final device internally, which gives the firms full control of key competences or technologies; this model is difficult to realise due to high resource requirements.

Our findings also suggest that when an industry is in its early stages—before any technology has become dominant—there is generally higher asset specificity among technologies than in mature industries. The high asset specificity limits the number of suppliers and contractors, which increases the likelihood that some of the focal firms cannot choose the buy option since there are few relevant components available to buy and integrate. However, our case companies also struggle to engage suppliers, particularly when the suppliers need to take part in a technology development process but also when there is a need to modify existing technology. This is because of the high uncertainties related to technology development, policy frameworks, funding and future end-markets. Our case companies found engaging large suppliers to be more difficult than engaging small suppliers. Small suppliers are often more flexible with regard to customisation and product modification than larger suppliers. On the other hand, larger suppliers are generally not interested in small-scale production and are hard to convince of the potential of 'unproven' technologies in an emerging industry. However, larger suppliers are usually very trustworthy in terms of delivering what is promised, and can also scale up production if necessary.

4.4 Research Paper 4: 'The entry of MNCs into an emerging industry: the choice of entry mode and the role of uncertainty'

Research question:

- Why did the MNCs choose their specific entry mode?
- How did uncertainty affect the choice of entry mode into the emerging tidal energy industry?

Background:

The complex technology development process in the tidal energy industry, which is very capital-intensive, time-demanding and dependent on public support, makes it very hard for new and independent firms to attract the necessary resources to take the technology the last steps from full-scale testing to commercialization. This, combined with the global potential of the industry and technological similarities with other renewable energy industries, has attracted several large MNCs. These MNCs entered the tidal industry from 2009 and beyond through internal development, acquisitions of start-ups and minority investments in start-ups. This paper focuses on these MNCs' motivations for entering the tidal energy industry, the MNCs' choice of entry mode, and how uncertainty affected this choice.

Method:

The paper uses a multiple-case study of five large MNCs to explore their entry mode strategies in the tidal energy industry. The case companies all have a global presence in related industries, such as hydropower, wind power or power generation. The primary data sources are interviews with company representatives in the MNCs and senior managers in the SMEs which they have invested in or acquired. Overall, the primary sources are based on 11 interviews, which lasted between 30 and 50 minutes. In addition, secondary data sources, such as websites, news, press releases, industry reports, and international industry-specific conferences, were used in preparations for the interviews and to build the cases. All of the interviews were transcribed and manually coded, and case reports of 4–6 pages were sent to the interviewees for approval and to ensure construct validity. The five individual cases were analysed before conducting a cross-case analysis related to different entry modes.

Key findings:

Four of the five case companies entered the tidal energy industry to become industry leaders, and these four firms believed they could utilise existing technological knowhow, supply chains and networks from existing operations, primarily in the hydropower industry and the wind power industry. The last case company had a completely different view as its main motivation for entering the industry was to be a supplier of various products in the industry's value chain.

The paper divides the five case companies into a 'Flexibility' group and a 'Control' group based on their choice of entry modes. The 'Flexibility' firms have chosen minority investments as their entry mode because they prefer a step-wise involvement due to the many uncertainties regarding stabile political frameworks, technology development and end-markets. These firms were cautious of the environmental uncertainties and wanted to learn more about the emerging industry from the inside before increasing their investment. The 'Control' firms have chosen entry modes such as acquisition or internal development; the most important factor for them is to have control over strategy and technology development. They believed utilisation of their pre-entry resources, such as technology expertise and industry knowledge, would overcome the uncertainties regarding technology and industry development.

Furthermore, the study distinguished between exogenous and endogenous uncertainties; the first are largely unaffected by actions of the firm while the latter may possibly decrease through the actions of the firm (Folta, 1998). In the paper, it is demonstrated how specific exogenous and endogenous uncertainties related to an emerging industry could affect the choice of entry mode and how the 'Flexibility' group uses RO logic while the 'Control' group uses TCE logic when assessing the uncertainties.

From the SMEs' perspective, the MNCs' investments are needed and were targeted by most of them for several years as they struggled to acquire the necessary capital to have a continuous progress. The SMEs highlight the increased credibility that came with MNC ownership and, especially, the funding necessary to bring the technology development towards commercialization. The SMEs also find the gradual investments where MNCs come in as minority owners and later, increase their ownership—beneficial when being included in large bureaucratic firms.

5 Methodology

This section includes an overview of the case study design, data collection, and considerations regarding strengths and weaknesses of the methodology. Each of the four papers has its own methodology section, so this section will mainly present and discuss issues not presented in the papers.

5.1 The case study design

The research context and the nature of the research questions set requirements, limitations, and boundaries on the type of data collection to be used in this dissertation. The thesis aims to increase the understanding of new technology firms in the early stages of an emerging industry, and there are several reasons why a multiple-case study approach was chosen for the four papers. First, a case study approach was a natural choice as it is the most flexible research design; it is suitable for obtaining a complete and detailed picture of social phenomena when depth is preferred over breadth and when the research is exploratory rather than confirmatory (Gerring, 2004; Yin, 2009). Second, in contrast to quantitative research, which often studies a variety of settings to increase the generalizability of the research (Miles & Huberman, 1994), this thesis aims to develop context-specific knowledge, which case studies are especially good at (Flyvbjerg, 2006). Third, the research questions seek to explain conditions that are present, and they start with *why* and *how*, for which, according to Yin (2009), case studies are ideal. Fourth, the limited research on new technology firms in emerging industries is a field that calls for more in-depth research and, especially, more qualitative approaches, such as archival studies and case studies (Forbes & Kirsch, 2011). According to Forbes and Kirsch (2011), the field of emerging industries has a poorly developed theory framework and, thus, needs empirical research to provide 'a suggestive theory' rather than formal tests of existing theory. They call for more research within the emerging industry field and, especially, more 'real-time' qualitative research, which can provide rich and detailed data (Forbes & Kirsch, 2011). Moreover, they argue that such primary data sources as interviews, surveys and observation are important, but they also advocate for active use of secondary sources, such as websites, business plans and press releases from both industry firms, customers, suppliers and investors, which later on might be more difficult to obtain. Furthermore, a multiple-case study approach was chosen in all the papers as this can provide robust results and allows the comparison of similarities and differences across cases. All four papers within this thesis were inspired by the framework and case study methodology developed by Eisenhardt (1989) and Yin (2009).

Table 6 below gives an overview of the multiple-case studies used in the different papers. Overall, they constitute 26 case studies. However, the primary sources (the interviews) in six of the case studies in Paper 3 are the same as in Paper 2; these interviews both focused on the investor side, the supplier side, and technology development of the case companies.

Table 6: Case study characteristics

Paper	*Type of study*	*Unit of analysis*	*Purpose*
#1	Multiple-case study	Eight Norwegian wave and tidal energy firms	Investigate the extent of early internationalization among new ventures in an emerging industry
#2	Multiple-case study	Six Nordic wave and tidal energy firms	Investigate the value-added role of different type of investors
#3	Multiple-case study	Seven Nordic wave and tidal energy firms	Investigate the evolution of supply chains in an emerging industry
#4	Multiple-case study	The tidal energy division of five MNCs	Investigate the entry strategy for MNCs into an emerging industry

Case selection

Although the ideal number of cases does not exist, the thesis followed Eisenhardt’s (1989) suggestion of 4–10 cases in multiple-case studies. This makes it possible to present the cases with some depth to the reader; it is a manageable number to conduct analysis on and a big enough number to use replication logic and also to separate into groups (Eisenhardt & Graebner, 2007). The selection of cases is described in each of the four papers but, generally, the selected cases were chosen because they had a history relevant to the research questions. In addition, the firms were willing to participate, were situated within a manageable travelling distance (Europe) and all had secondary data available in understandable languages (local language and English). Furthermore, the selection of cases followed a logic of exploring relatively similar cases within a specific context (Eisenhardt, 1989).

The case companies in Papers 1–3 are all small (4–60 employees) and relatively new firms within the wave or tidal energy industries. In Paper 4, the focus is on the entry of larger firms into the tidal energy industry, and the case companies are large MNCs (> 20.000 employees). In addition, interviews with small tidal energy firms in which the multinationals have invested is utilised as part of the cases and to strengthen construct validity (Yin, 2009). The total number of companies in the emerging marine energy industry is limited, and they are also widely spread around the globe, with around two-thirds of them situated in Europe (Mofor et al., 2014). When identifying possible companies for my case studies, different sources, such as national and international public agencies, industry organizations and industry websites (e.g. Renewable UK, Ocean Energy Systems, International Renewable Energy Agency, Tidal Today) were used to develop a database of firms.

5.2 Data collection

The data, which the case studies are based upon, are the combination of interview data and other complementary secondary sources, such as news articles, press releases, web pages, industry conferences and industry-related reports.

For the data collection of Paper 1, two students, Birthe Sønning and Ida Sølvskudt, were central. They were writing their master's project and thesis on an assignment made by me. Before they began their work, they received extensive information about the marine energy industry and, also, the details of all existing Norwegian marine energy firms. Together with the students and my supervisor, Øystein Moen, an interview guide was made. Following this, the students were prepared to conduct interviews and to find secondary data sources. In total, they did interviews with eight companies in the autumn of 2011, which, in combination with secondary sources, were developed into case studies. I found these cases very interesting and collected additional data material on them from meetings and presentations on conferences, updated news and webpages, and publicly available consent applications.

In 2012/13, six case studies on Nordic marine energy firms were conducted. This was done in collaboration with a Finnish master student, Niko Ristola. Since he speaks Finnish, otherwise unavailable secondary sources of the Finnish case company became available. My own fluent understanding of Swedish and Danish made several secondary sources available for all case companies. These six case studies are used in Paper 2 and Paper 3. One of the case studies used in Paper 3 was conducted by three other master students that I supervised. These students wrote a project assignment on industry partnerships and collaboration within Norwegian, Danish and Scottish wave energy companies. Here, they also focused on supply chains, but only one of the case studies had a rich enough history, information and secondary data material to be included in a multiple-case study analysis together with the six case studies I had conducted the year before. In addition, the same three master students conducted the case studies used in Paper 4. As with the data collection for Paper 1, the students were working on an assignment made by me, and they received extensive information about the marine energy industry. Furthermore, we designed the data collection process and made the interview guide together, and the students were thoroughly prepared by me to conduct interviews and to identify secondary data sources.

Before conducting the interviews, all interviewers acquired a very good knowledge of the industry by examining secondary sources. This saved a lot of time in the interviews as we did not need an introduction to the complex industry or the firm itself. Furthermore, it made the interviews more focused and allowed us to reach the point of the investigation more directly.

5.3 Evaluating the research design

There are several relevant tests that can be applied to judge the quality of the research design used in this thesis. *Construct validity* relates to the critical question of whether the study measures what it is supposed to measure. As suggested by Yin (2009), this thesis has used multiple sources of evidence to increase its construct validity. First, two types of data are used in all case studies, semi-structured interviews and public available documents; these include reports, websites and press releases but also presentations and informal meetings at international marine energy industry conferences. Using two different types of data allows for triangulation, which is the inclusion of two or more dissimilar research methodologies that do not have the same weaknesses and strengths (Jick, 1979). Second, at least two members of the research group, allowing for investigator triangulation (Patton, 2002), conducted all interviews. Third, all case study reports were sent over to key informants so these could approve or correct potential misunderstandings and errors; this also increased the construct validity of the thesis.

The multiple-case study design used in all papers in this thesis has increased the *external validity* of the findings in each paper as they are generalizable beyond the specific firm. However, this entire thesis could be described as a single-case study of the marine energy industry. This means that the transferring of the findings' implications to other emerging industries must be done with specific care. The *reliability* of the data relates to the data process, the data used, and the collection and analysis methods employed (Yin, 2009). To meet the criteria of reliability, this thesis and its individual papers provide a detailed description of the cases and methods and the reason why these cases and methods were chosen.

Critical reflections

Other research designs, such as quantitative approaches, were considered for use. This might have been valuable in order to generalize the findings based on a larger sample. However, with the limited size of the marine energy industry, this was determined to require much work with a limited and uncertain payoff. Overall, the use of qualitative case studies has provided this thesis with rich information on how new firms operate and interact with other stakeholders in the development of the emerging marine energy industry.

A weakness in the methodology is the fact that I did not have full control of the entire data collection process in all cases; several interviews were not conducted by me. However, I have tried to limit this weakness through co-developing interview guides, preparing the interviewers, always be at least two interviewers and the extensive use of secondary sources to verify and expand information. These actions have made me confident that the quality of the case studies is very good.

6 Discussion

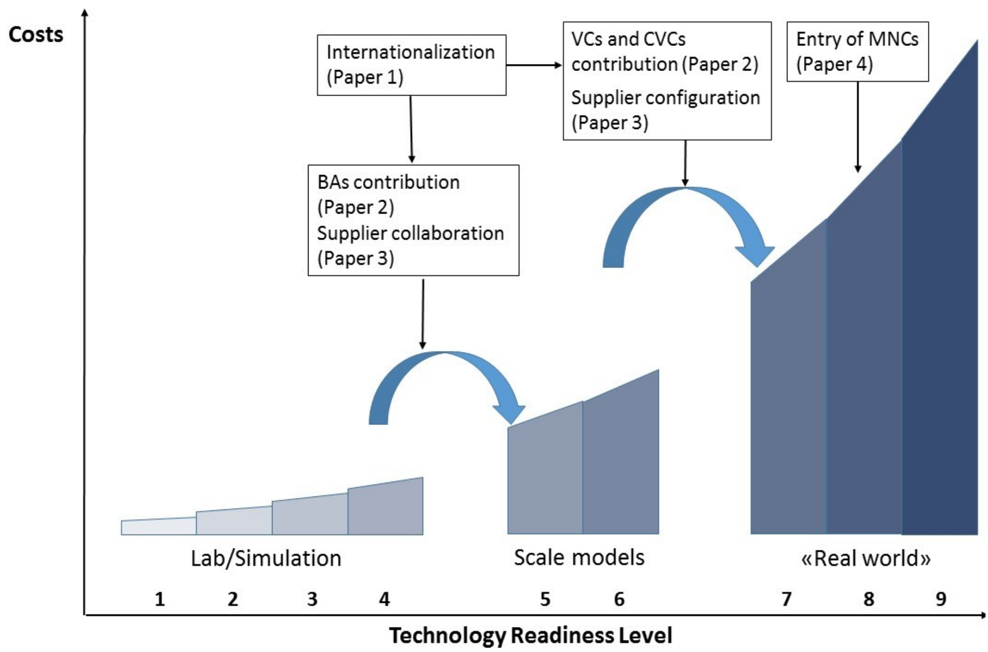
In the introduction, the main research question of this thesis was presented: 'How can new firms develop and commercialize novel and resource-demanding technologies in a complex emerging industry?' Throughout the four papers of this thesis, this question has been investigated through various theoretical frameworks and through the perspectives of both entrepreneurial firms and large entrants. This chapter will first elaborate on how this thesis has answered the overarching research question. Second, it will summarize contributions to research and implications for practitioners. Then, limitations of the thesis and suggestions for further research will be discussed, followed by the author's personal perspective on the further development of the marine energy industry.

6.1 New firms developing novel technology in an emerging industry

Surviving the 'valley of death' is a challenge for most new technology firms; more specifically, the central challenges for firms in the marine energy industry are lack of capital, technology development and available infrastructure (Krohn et al., 2013; OES, 2015). The four papers in this thesis have all studied new firms' interaction with various stakeholders to overcome challenges related to funding and technology development. This include how interaction with funding sources and potential suppliers and partners in different stages of the technology development process can help new firms reach milestones and move the technology further towards commercialization.

Figure 6 below shows that the technology development towards commercialization is long with increasing costs. It also illustrates how the four papers of this thesis address different themes relevant for how new firms can overcome major challenges in various stages of the technology commercialization process in an emerging industry. The y-axis in Figure 6 shows the costs while the x-axis shows the technology development by using the TRL, which describes the maturity of the technology. Level 1 describes the basic principle of a technology while Level 9 describes technologies ready for commercial use (see also Figure 4 on page 15). In Figure 6, the TRL is divided into three main areas inspired by Nielsen (2010): *Levels 1–4* represent the applied and strategic research level (proof of concept) conducted in a controlled environment. *Levels 5–6* represent the validation of the technology on a large scale in a relevant environment, such as at ocean sites. *In Levels 7–9*, the technology and subsystems are tested and validated as a full-scale prototype at an ocean site and should successfully generate electricity over a long period. In addition to the large increase in costs, the move along the TRL is also technologically challenging, with an increase in size, quality, complexity, infrastructure and manufacturability for components as the testing develops from the laboratory to test tanks, to protected ocean sites and, finally, to arrays of devices generating electricity. Thus, the demand for technology development expertise and financing is increasing.

Figure 6: A model of how new firms can overcome barriers in the commercialization process



Moving out of the laboratory

As seen in Figure 6 above, there is a significant gap both technologically and financially between TRLs 4 and 5. This is because the technology develops from small-scale tank testing to large-scale testing in an ocean environment. In this phase, the development and production of components, installation, testing and documentation of results leads to a significant increase in costs and a need to identify and engage suppliers of components.

In Papers 1, 2 and 3, the thesis addresses how new firms can overcome this financial and technological gap. In this stage, public funding, such as research grants and start-up grants, are important financial sources, but the firms also need private capital. Papers 1 and 2, like earlier research on new technology firms (Harrison & Mason, 2000), finds that business angels (BAs) are the most important providers of private capital in this early stage. Additionally, the non-financial contributions of BAs in areas such as business administration and strategy are important, but the findings in Paper 2 highlight the BAs' ability to help the venture access additional funding sources and relevant technology partners as earlier described by Sørheim (2005) and Mason (2007). This is illustrated by some of the BAs in Paper 2, which spent up to 80% of their time working for the firm through the board, utilising their network to meet potential new partners and investors. Such investor contributions could be invaluable in emerging industries when the firms need to move the technology from the laboratory and to large-scale testing in relevant environments.

The move between TRLs 4 and 5 also means that firms must engage suppliers to deliver components, initiate technology development partnerships or make components themselves. In Paper 3, we identify and discuss different supply chain configurations. There is limited research on supply chain configuration in emerging industries (Baril, Harrington, & Srai, 2012), but in the early stages of complex emerging industries such as the marine energy industry , there is typically high asset specificity among technologies since there exist no 'dominant design' (Abernathy & Utterback, 1978). The high asset specificity limits the number of suppliers and contractors, which increases the likelihood that firms will only be able to buy existing off-the-shelf components. However, this means that most new firms need to develop new components or modify existing ones, and in the early stages of technology development, this is often done through expensive one-off projects. Thus, firms need to identify and engage flexible suppliers willing to deliver small and customized components. In Paper 3, we find that such suppliers are often smaller and more flexible firms because larger firms are typically not particularly interested in small projects with high uncertainty both technologically and commercially.

Making the move to the 'real world'

As illustrated in Figure 6, the gap between TRLs 6 and 7 indicates a huge increase in costs and a move in technology development from large-scale to full-scale devices. The dramatic increase in costs when testing full-scale models could be partially covered by public funding schemes, but attracting considerable amounts of private capital in this stage, mainly through VCs or larger firms, is necessary. In line with earlier research (e.g. Maula et al., 2005), Paper 2 finds that having larger firms as investors is especially beneficial as these can help strengthen technology development; additionally, the findings indicate that their main contribution is to increase the legitimacy of the new firm. This is very important in emerging industries (Aldrich & Fiol, 1994; Jacobsson & Bergek, 2004), and it can strengthen the new firm's credibility when dealing with external stakeholders such as suppliers, investors or policy makers and help the new firm access more funding and technology competence or open the doors to new markets and customers.

The move to full-scale prototypes implies increasing requirements for the manufacturability of the different components. The choice between what to make internally and what to buy in the market (Williamson, 1975) becomes more important as does *who* the different suppliers or partners should be. In Paper 3, several of the case companies replace some of their smaller suppliers with larger and more renowned suppliers when they start developing and producing full-scale prototypes. These large suppliers are, in many cases, not interested in developing new technology or modifying their existing products for small deliveries to new firms that are far from having any commercial product. However, when the technology has been proven through extensive testing, the larger suppliers can more easily see the potential of the technology. Although larger suppliers are typically more difficult for new firms to work with than smaller suppliers, their trustworthiness in delivery, their ability to scale up production and their international presence are factors which could increase the quality and credibility of the new firm's technology.

Towards the finish line

On TRL 9, the technology should be commercially viable, which in the marine energy industry means that an array of full-scale devices are tested and qualified for commercial use (Nielsen, 2010). The move from TRL 7 to TRL 9 represents large investments in technology development and testing. This is a difficult step for new firms to manage, even those with considerable external funding and/or technology partnerships, and many firms target industrial investors in this stage. Paper 4 shows how large MNCs prefer to enter the emerging tidal industry through acquisitions or minority investments in smaller firms which have developed their technology to TRLs 7–9, i.e. proven the technology in full scale. The paper further shows how MNCs can help strengthening the quality and reliability of the technology, utilising their own production facilities and global supply chains and investing the necessary funding into technology development. Moreover, the entry and commitment of MNCs increases the legitimacy of the industry towards policy makers and end-customers, such as utility companies. The MNCs can offer relevant warranties and guaranties for the technology that are difficult for small firms to offer to the end-customers but which are critical for the commercialization of the technology. Furthermore, in the case of the tidal energy industry (Paper 4), the fact that the entering MNCs have all targeted the horizontal axis design has major implications for the selection of a 'dominant design', as it most likely will be harder for firms developing other technology designs to acquire funding.

An international perspective

This thesis also shows that having an international orientation from inception could be crucial for new firms in the marine energy industry. In Paper 1, the case firms with international activity were more successful than those without in accessing technology partners and both private and public funding. The international perspective was equally important among the case companies in Papers 2 and 3, where the case companies have a large share of their investors and suppliers from all over the world, but especially from Europe. This indicates that, in small and emerging industries where potential partners and investors are limited and difficult to identify, international engagement can increase the amount of relevant stakeholders available to help the new firm overcome major challenges in the commercialization process.

Overall, Figure 6 displays how the papers in this thesis are linked together. Furthermore, it summarizes the findings of this thesis with regard to how new firms could bring new technology towards commercialization in an emerging industry through strategic decisions and interactions with external stakeholders. Although this model could only explain parts of the commercialization process for some firms since there are many different possible combinations of investor types, investor timing, internationalization patterns and supplier relationships possible, it can help to increase the understanding of how new firms can interact with different stakeholders to overcome crucial challenges in bringing forward novel technologies in new industries.

6.2 Contribution to research

The main contribution of this thesis is central in all four papers: describing and explaining how new firms are able to develop novel technology in a complex emerging industry. A common feature for all the papers included in this thesis is that it is difficult to identify literature which have done similar studies in the context of emerging industries, which highlights the relevance of this thesis. Moreover, the four papers contribute to the fragmented literature on emerging industries, in which there is a lack of studies on how new firms interact with actors such as different investors and technology suppliers (Forbes & Kirsch, 2011; Gustafsson et al., 2015). By presenting how new firms interact with different actors in the commercialization process, the thesis addresses the lack of research on how new firms overcome *the trifecta of burdens* such as their own liability of newness, the industry's lack of legitimacy and structure, and the new technology's inherent uncertainty (Woolley, 2014). The overarching result of this research is presented in Figure 6 above (page 38), and it is the only study, to the author's knowledge, which takes the view of technology developing firms from the idea generation phase towards commercialization in a complex emerging industry. More specifically, the thesis have tried to explain how new firms through an international engagement and interaction with different investors, suppliers and MNCs are more likely to overcome crucial gaps in the commercialization process.

A second contribution is the focus on international upstream activities of new ventures in the pre-sale phase, which is an understudied area of international entrepreneurship (Hewerdine & Welch, 2013; Rasmussen, Madsen, & Servais, 2012) that is important to understand since the willingness among several companies to, already in the pre-commercial phase, move activities and establish subsidiaries abroad are likely to influence their future internationalization patterns and activities (Madsen & Servais, 1997). Paper 1 finds that a firm's international activities prior to its first sale can be extensive and, for industries with long technology development periods, such activities could be of vital importance for securing access to crucial funding and technology competence. These findings are further supported in Papers 2 and 3, where the majority of the case companies have considerable early international activity towards investors and suppliers, and test scale models of their devices abroad. In addition, the thesis shows how public funding programmes have a strong impact on the re-localization of activities (Løvdal, 2011), especially when they are connected to technology development programs that also demand local presence and/or local partners. Finally, Paper 1 suggest a modification of Oviatt and McDougall's (1994, p.49) definition of an INV that includes international sourcing activities.

A third contribution is the detailed study of how different types of investors add non-financial value to new technology firms in the early stages of an emerging industry. This contributes to the entrepreneurial finance literature and to the understanding of different investors' involvement and contribution to new technology firms, which is an understudied area (Large & Muegge, 2007; Luukkonen, Deschryvere, & Bertoni, 2013). The study is one of few studies comparing different types of investors' value-added from the demand side (i.e. seen from the company's point of view)

(Sørheim, 2012). Thus, the focus has been to identify which positive investor contributions, active or passive, that the *entrepreneurs* experience as important in the early stages of an emerging industry, and not what different investors do and believe are important. Furthermore, the findings in Paper 2 indicate that the external contributions, in which the investors actively or passively help to attract new resources or strengthen previously existing ones, are most important for new technology firms in emerging industries. Although the study supports earlier findings that VCs make a range of positive contributions to firms in emerging industries (e.g. Dimov, de Holan, & Milanov, 2012; Von Burg & Kenney, 2000; Zook, 2002), this study also suggest that VCs have a limited role in such early stages of an industry because the risk is too high and the time perspective is too long.

A fourth contribution is the study of supply chain development in emerging industries, which is an area where little research is conducted (Baril et al., 2012). In Paper 3, three different models for supply chain configurations in the early stages of an emerging industry is suggested. The models are designed by analysing two classic supply chain design parameters: the make-or-buy decision (Walker & Weber, 1984; Williamson, 1975) and the weak versus strong ties of supply chain relationships (Cooper, Lambert, & Pagh, 1997; Williamson, 1991). The choice between the three proposed models —the Market, the Ally and the Maker Models—are mainly a result of the *asset specificity* of the technology and the *acquired funding* of the companies. The lack of a 'dominant design' among technologies in the marine energy industry leads to huge variations in technologies under development, with the result that many have high asset specificity. This high asset specificity limits the potential suppliers and contractors, which increases the likelihood that firms cannot chose to buy from suppliers in such an early stage of the industry. Thus, new firms in the marine energy industry either must raise the necessary funding to develop and manufacture components themselves, or they need to identify and engage external firms to modify existing technology or develop new technology. However, the limited track record and credibility that new firms in emerging industries possess (e.g. Aldrich & Fiol, 1994) makes it difficult to engage suppliers and partners for this purpose.

A fifth contribution is the study of relatively similar large firms entering an emerging industry, and the focus on the entrants' choice of entry mode. Paper 4 is the only study identified which compare different equity entry modes into the same emerging industry from the perspective of MNCs operating in similar adjacent industries. It contributes to emerging industries literature (Forbes & Kirsch, 2011) and to the literature stream on uncertainty and entry modes (Tong & Li, 2011). The paper builds on earlier studies of uncertainty and entry modes (e.g. Billitteri et al., 2013; Folta, 1998; van de Vrande et al., 2009), and analyses the choice of entry mode by applying RO and TCE logic when facing endogenous and exogenous uncertainty. The findings suggest that relatively similar firms assessed the same uncertainties differently, based on whether they used a RO or TCE perspective. Furthermore, the findings suggest that these assessments of endogenous and exogenous uncertainties in combination with the MNCs' pre-entry resources, the degree of competitiveness and the preferences of the SME they invested in or acquired, affected the choice of entry mode into the emerging tidal energy industry.

6.3 Implications for managers

International focus from inception could be vital

With an international focus from inception, new firms will have a larger potential to access limited resources, such as funding or technology competence, in the early stages of technology development. In Paper 1, the firms without international activities acquired far less funding and technology partners than those with international activities. Those firms will most likely have a longer path to the commercial market than the early internationalizing firms because of their relative lack of funding and limited partner opportunities nationally. Similar to Løvdal (2011), this thesis also demonstrates how firms can exploit international opportunities created by different national policy regimes related to funding and technology development programs in the emergent stage of an industry. Furthermore, the findings also suggest that having international market-related activities already in the pre-commercial phase, could help firms accessing necessary resources. For instance, some of the case firms have targeted promising niches within the marine energy industry that only exists in certain areas such as isolated (island) communities or off-grid offshore installations such as salmon farms where the energy prices are much higher than in areas connected to a grid. This strategy has separated these firms from most other developers and helped them finance their first pilot tests. Thus, this thesis show how important it can be for firms to have an international perspective from inception both on upstream and downstream activities.

Is chasing VCs worth the time and effort?

The findings in this thesis suggest that VCs' role in the early stages of complex emerging industries, before any design is dominant, is limited. High uncertainty within both technology and markets, mixed with high capital requirements and a long time perspective, make for an environment that is a poor match for most VCs. Although VCs typically are easy to identify and often play important roles in the commercialization process of firms (e.g. De Clercq et al., 2006), this thesis shows that VC investments can be very hard and time-consuming to acquire. Additionally, the VCs usually have a relatively short time perspective on their investments compared to the long technology-developing period of the marine energy industry (Leete et al., 2013). Thus, new firms in the early stages of complex and capital-intensive emerging industries must consider whether the time and effort used in chasing VCs, with limited possibilities for success, is worth it. However, in circumstances when there are VC funds with an investment focus on a specific emerging industry or technology (e.g. renewable energy VCs), those VCs should be targeted by firms needing VC investments.

An attractive investor path towards commercialization

Actively contributing investors in different stages of the commercialization process could be an attractive investor path for firms in emerging industries. As illustrated in Paper 2, different investors have different financial and non-financial contributions to offer, and these typically match the needs of new firms in different stages of the commercialization process in complex emerging industries. Thus, having engaged BAs in the early stages of development, followed by investments and contributions from established and renowned companies in later stages, can help a firm address the most critical challenges in each development stage. However, considering the challenges with socio-political legitimacy in addition to the technological and financial challenges facing new firms in complex emerging industries, it is important that the firms actively target investors with the intent and capability to supply non-financial contributions.

Find and engage the right suppliers and partners

New technology firms should try to engage relevant and realistic partners in the different stages of technology development. In the early technology development stage, when technology is only tested one-off and in small scale and thus not 'proven', smaller suppliers could be more flexible, easier to engage and easier to collaborate with than large firms. In addition to being bureaucratic with limited flexibility, large firms can also be reluctant to collaborate with a new firm when there is high uncertainty related to the technology and its future potential. However, large firms' reputation, trustworthiness and flexibility in scaling up production shows their value as suppliers and partners, especially in the later stages of the technology development. Thus, a possible path could be to engage smaller suppliers in the earliest stages and larger suppliers later in the commercialization process.

6.4 Implications for policy makers

Firms adapt to (changing) political frameworks

Many complex industries are dependent on public support schemes in the emerging phase (Funk, 2010; Mazzucato, 2013a). However, huge differences in national support schemes increases the risk that companies will move their activities to other countries with more favourable support schemes before they begin to generate income, despite having received considerable soft funding in their home country initially. In addition, the findings show that stabile and attractive policies are crucial for established and larger firms to enter complex emerging industries such as the marine energy industry in the early stages. Although they are rarely first movers, the entry of large firms into emerging industries brings considerable investments and activity, which are important for the specific firms being invested in, the emerging industry and possible also the local or regional community. Such implications should be carefully considered when creating support schemes for emerging industries.

A home market is needed to grow a marine energy industry

The findings in this thesis imply that without an end-market or a national test market where companies have the opportunity to test full scale prototypes, the best possible scenario for countries like Norway is that new firms keep their headquarters locally, but place manufacturing and sales abroad. Such firms are most likely to be those of 'the Market model' or 'the Ally model' as described in Paper 3. Firms of 'the Maker model', (i.e. in-house production of components/devices) are less likely to move abroad when they have invested in production facilities and developed knowhow related to the manufacturing process. Such production facilities are, however, probably only established in the first place if there are possibilities to test full scale prototypes locally. Thus, it is unlikely to build up complex emerging industries such as the marine energy industry, which includes local manufacturing and local suppliers, in countries like Norway unless the technology developing firms have the possibility to test or sell their devices locally/nationally. This can further be exemplified by the UK and particularly Scotland who has had a long term focus on developing the marine energy industry. By having attractive financial support in all stages of development, infrastructure for testing and developing technologies and a focus on supply chain development, Scotland has become the global hotspot for the marine energy industry.

Co-development of funding mechanisms and the commercialization process

This thesis shows that the development of emerging industries such as the marine energy industry requires *patient capital* (Mazzucato, 2013b). This implies that, in addition to develop stable public funding regimes, policy makers should downplay their focus on private investors such as VCs in the early stages of emerging industries and instead focus on sources of patient capital such as involving larger technology firms. A co-development of funding mechanisms and the stages of the industry development where public policy is aimed at incentivizing private individuals, BAs and small firms in an early stage, and larger firms such as MNCs in later stages of technology development, is required.

Increase the focus on supply chain development

As seen in Paper 3, emerging industries may suffer from an underdeveloped supply chain in the early stages, especially before any technology is dominant. In the marine energy industry, there are many publicly funded technology development programs (as seen in Paper 1), but these often include support for different projects involving only one technology developer and its partners. Governments should have stricter demands of participants in these projects so that the participants share some of the knowledge gained from the publicly funded program with other industry actors or make some of the knowledge publicly accessible. Especially when the technology development programs develop solutions relevant for many actors in the industry such as mooring solutions in the marine energy industry. This could increase the progress of technology development in the industry but need to be carefully designed so that firms still are willing to participate. In addition, publicly funded programs should try to identify challenges in the supply chain that are common among different marine energy technologies and develop technologies or methods with high relevance for multiple technology developers. This will help to recruit more suppliers into the industry and create less customized solutions, which will lower costs and strengthen technology development.

6.5 Limitations and suggestions for further research

This thesis has several limitations which provide potential avenues for further research on new technology firms in emerging industries. First, the thesis can be characterized as a single-case study because all primary and secondary data are from the marine energy industry. This means that the results cannot—and are not intended to—be transferable to all other industries. However, the results can provide insight into other capital-intensive and complex emerging industries with similar challenges, such as other clean technology or renewable energy industries. To increase the transferability of the thesis, further research might explore new firms in other emerging industries with similar characteristics and challenges.

All the case companies in this thesis are from Northern Europe (Norway, Sweden, Finland, Denmark and the UK), and although secondary sources, e.g. industry reports and international conferences suggest that start-ups in other contexts face similar challenges and opportunities, the study's geographical concentration is a limitation. This is especially the case in the study on internationalization (Paper 1), which only consists of Norwegian companies. Although we observe similar patterns from our Danish, Finnish and Swedish case companies in Papers 2 and 3, it is uncertain whether the international aspect is as important for firms originating in countries with attractive policy regimes for the emerging industry, such as the UK. Similar studies of international activities among new firms in other emerging industries or industries with long technology development periods would also be interesting. Moreover, with the limited number of cases in the studies, there is a danger that the results are sensitive to the specific case selections. Thus, there is a need for larger quantitative surveys to further investigate the role of new firms in the commercialization process of novel technologies in emerging industries.

Few of this thesis' case companies were close to commercializing their technologies at the time of data collection, and this adds several potential limitations to the thesis. First, as the data is gathered in 'real-time', we do not know if any strategies will be more successful than others in commercializing the different technologies. Second, the data are based on the firms' development thus far and their plans for the future and, thus, do not capture potential events and decisions that may change before commercialization. Third, the inclusion of only successful and existing companies in Papers 2 and 3 ignore that other companies no longer active in the industry could have had similar inputs from investors as our case companies in Paper 2, without successful results. Thus, it is necessary to conduct more longitudinal studies to investigate the complete development over the commercialization phase. Future studies should also use long-term outcome measures and compare successful and unsuccessful start-ups to better understand the effects of different strategies in an emerging industry.

Most of the data in Papers 1, 2 and 3 comes directly from managers in new firms. While this data can give valuable insight from the focal firms' perspective, it might be myopic. Representatives from other stakeholders, such as investors, partners and policy makers, could have views on issues that might add value to, or even contradict, information from our primary sources. Thus, future research should also examine the issues from the perspective of investors and partners.

This thesis also has some theoretical limitations. By using the different theoretical frameworks applied in the thesis, there is a risk that some mechanisms have been overemphasized while other mechanisms useful for understanding and investigating the research questions have been downplayed or not recognized at all. Thus, there is a need for research on new technology firms in emerging industries which apply other theoretical frameworks.

Further suggestions for future studies

This thesis has revealed interesting findings related to new firms' interaction with different stakeholders in an emerging industry, and many of these findings are great starting points for further studies. First, the findings in Paper 1 show a need for more studies on INVs and upstream activities close to inception, especially how the strategic choice to internationalize affects internationalization patterns and development of partnerships, manufacturing, end-markets and financing of a company in the long run. More studies on how globally emerging industries develop and how resources and technology is spreading, is also needed. Second, there is a need for more research on investor involvement in emerging industries. Specifically, the staging of capital and interplay between investor types for new technology firms is understudied and needs further attention. The co-evolution of both public and private financial institutions and technology firms in complex and capital-intensive emerging industries is also an interesting research avenue with possible important implications for policy-makers.

Third, the configuration and development of a supply chain is understudied in emerging industries. More studies on how new firms identify and engage partners and suppliers in emerging industry contexts, preferably with a perspective from both sides, is needed. In addition, following up the findings in Paper 3, more studies on how firms' make, buy or ally decisions develop over the course of the commercialization phase would be interesting. Fourth, as most of the literature on acquisitions is between large firms, more studies on the acquisition process when very large firms acquire small start-ups would be welcome. Fifth, MNCs could have a special interest and specific advantages in globally emerging industries since they might have the possibility to manufacture and sell globally, and their global name and network is highly relevant in such politically influenced industries as renewable energy industries. For new firms, MNCs can have different roles such as partners, suppliers, investors, owners, customers or competitors. Thus, more studies on the relationship between MNCs and (international) new ventures is welcome, especially in the context of emerging industries.

6.6 The future of the marine energy industry

Having followed the development of the marine energy industry since 2010, I have some thoughts on crucial aspects and future scenarios.

A precondition for positive development of the marine energy industry is the continued commitment and patience from policy makers, especially in the UK, to prove the viability of the technologies and show the potential of the industry. However, it is critical for the industry that the large projects currently under development meet their targets. This is important since the marine energy industry has relatively low credibility among policy-makers and industry due to its slower-than-expected progress and several disappointments over the last decade. Further disappointments increase the risk that patient capital, such as the MNCs, will exit the industry or that policy frameworks will be less attractive.

Furthermore, I believe that the divide between tidal and wave energy will grow, at least in the short to medium term. In the tidal energy industry, there are currently two branches with different opinions on how to reach commercialization. There are the industry leaders who target large turbines from 1 MW and up and some other firms who are testing much smaller horizontal axis turbines. The philosophy of these firms is to use small floating turbines because these are much easier and less costly to deploy and test, and can be used on already existing constructions.

The biggest opportunity for tidal energy, however, is to develop technologies commercially viable for harnessing energy from low-speed tidal currents and for shallower waters. Because most tidal areas consist of low-speed currents or have areas with low currents, the potential for the tidal industry may become much higher than estimated today. If such technologies become commercially viable, the potential energy output from tidal energy will increase dramatically.

For the wave industry, I believe the large-scale MW solutions are too immature and a long way from being commercially viable. I think two aspects, however, have potential in the short to medium term. First, hybrid solutions, such as wave and offshore wind together, might be relevant in the near future. Second, I believe that wave technologies targeting niche markets such as aquaculture, offshore installations, or off-grid communities could be important. These are markets that already face high energy prices, and it may be important for wave energy solutions to prove their technology's viability on a smaller scale and provide valuable data to investors and utility companies. I also believe that the variation of physical sites, closeness to shore, wave climate, and large variations of potential use will lead to several technological designs being commercially viable.

The obvious hope is that we, in the not too distant future, can utilise some of the massive forces of the ocean in a sustainable matter and that wave and tidal energy technologies are a natural part of the renewable energy mix.

7 Concluding remarks

Although new firms are important drivers of new innovative technologies, the limited resources of new firms is a clear disadvantage in capital-intensive and complex emerging industries such as renewable energy, where scale matters. This thesis has shown and discussed how new firms can overcome these disadvantages and can bring innovative technologies towards commercialization in a new industry by interacting with different types of investors, suppliers and large firms on an international scale.

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Part II: The Articles

Article 1:

New Ventures in an emerging industry: access to and use of international resources

ARTICLE 1

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New ventures in an emerging industry: access to and use of international resources

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Abstract: This paper addresses the international activities of young companies in the emerging marine energy industry. Our study is constructed based on interviews with eight companies combined with scientific reports and publications. The primary challenges faced by the companies are related to financing and technology development. Our findings indicate that the companies may be divided into three groups: a) three technology- and funding-driven international ventures; b) one market-driven international venture; c) four companies with limited international involvement. The short time span between establishment and the first major international activity initiated to acquire funding or technology competence is a distinct characteristic of the firms in the first two groups. The last group with no or limited international activity reveals an alternative path. Our study provides insights on significant firm-level differences with respect to international involvement in the pre-commercial phases of development and discusses the implications for researchers, managers and public policy.

Keywords: new ventures; international new ventures; INV; internationalisation; resource acquisition; emerging industry; pre-commercial; marine energy; ocean energy; technology partnerships; access to resources; entrepreneurship; small business.

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New Ventures in an emerging industry: access to and use of international resources

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Abstract

This paper addresses international activities of young companies in the emerging marine energy industry. We build our study on interviews in eight companies combined with scientific reports and publications. The main challenges for the companies are related to *financing and technology development.* Our findings show that the companies may be divided in three groups: a) three technology and funding driven international ventures, b) one market driven international venture and c) four companies with limited international involvement. The short timespan between establishment and first major international activity for acquiring funding or technology competence is a distinct characteristic of the firms in the first two groups. The last group with no or limited international activity reveals an alternative development path. Our study gives insight in significant firm level differences with regard to international involvement in the pre-commercial phase of development and discusses the implications for researchers, managers and public policy.

Keywords: new ventures; International new ventures; INV; internationalization; resource acquisition; emerging industry; pre-commercial; marine energy; technology partnerships

Introduction

The last two decades, research focusing on International New Ventures (INVs) and Born Global firms (BGs) has developed into a significant research stream as can be witnessed by the number of recent review articles as for example (Aspelund, Madsen, & Moen, 2007; Cesinger, Danko, & Bouncken, 2012; Jones, Coviello, & Tang, 2011; Keupp & Gassmann, 2009; Rialp, Rialp, & Knight, 2005). These types of firms are defined in different ways, but elements of speed, extent and scope (Zahra & George, 2002) of their international engagement are often used in definitions. Examples are firms having their first international activity within 3-8 years after inception (speed) (Knight, 1997; McDougall & Oviatt, 1996), 25 per cent international sales within the first three years after inception (extent and speed) (Knight & Cavusgil, 2004) and having active operations outside their own continent within two years after inception (scope and speed) (Laanti, Gabrielsson, & Gabrielsson, 2007). Existing definitions do, however, typically focus on firms that already produce and sell their product or service.

Rasmussen, Madsen & Servais (2012) state that there has been limited attention to the sourcing side of INVs/BGs and that few studies on the pre-sale phase have been published (Rasmussen, Madsen, & Servais, 2012).The lack of focus on the early phase before sales activities is surprising since authors generally agree that a venture's future internationalization activities and processes are heavily influenced by decisions made close to and before inception (Aspelund et al., 2007; Boter & Holmquist, 1996; Madsen & Servais, 1997; Sapienza, Autio, George, & Zahra, 2006).

We will focus on the international resource acquisition of new ventures in the pre-sale phase of their development (we will use the label INV for these firms if they have an international focus). More specific, case studies of eight companies in the marine energy industry (wave and tidal energy) will be presented. These companies are focusing on technology development and have not yet achieved their first sale since the industry as such is still in its very early stage of development.

We do assume, however, that the industry will prove to be highly global once economically viable marine energy solutions have been developed. We therefore also expect that firms in the industry will have an international focus during their pre-sales activities. Our basic research questions are:

- *What is the extent and scope of international funding and technology partnership among firms in the pre-sale phase in the marine energy industry?*
- *Why and how do such firms engage in international activities?*

- *Finally, we also consider what implications our findings may have for some of the most used definitions of BGs and INVs.*

We have chosen the marine energy industry as the empirical domain because this industry is characterized by having a long time horizon in product development, and the industry is also quite global in its structure and stakeholders. We therefore expect to identify interesting problems and processes related to the topic of this paper.

The marine energy industry

The marine energy industry is an emerging global renewable energy industry which consists of firms developing devices to harness energy from ocean waves and tides. Marine energy is believed to have a great potential due to large and accessible resources combined with placement of power plants outside the scope of user conflicts (Sandgren, Hjort, Pimenta de Miranda, Hamarsland, & Ibenholt, 2007). The industry is pre-commercial; in 2012 still no commercial plants have been installed. However, the first commercial marine energy plants are under way and forecasts project that total global investments in the industry during the period 2011-2015 will be £0.8 billion (Douglas-Westwood, 2011). The industry consisted in 2012 of around 150-200 firms and research has shown that the majority of firms in the industry are mainly young and small ventures (Løvdal & Aspelund, 2011).

This emerging industry is further characterized by several different technological solutions being tested and still no dominant design among either wave- or tidal energy developers. The technology development process is long and capital intensive with several rounds of small and large pilot tests in tanks and ocean environment. The full scale pilots are large physical structures, sometimes weighing hundreds of tons, and installing and operating them in harsh ocean environments leads to high costs for demonstration tests. A large part of the expenses related to demonstration testing is connected to needed infrastructure as grid connection to accomplish the tests. The total costs on developing a project from concept verification to full scale demonstration project has been estimated to £7m-£16m according to the Marine Institute of Ireland (Holmes, Nielsen, & Barrett, 2007), while for several technologies the costs for a grid connected full scale demonstration plant alone exceeds £10m combined with an expected testing period of at least 1-2 years.

The physical size of installations, the harsh ocean environments, the need of external infrastructure and the combination of several different technological skills make development of marine energy complex. The combination of complexity and high development costs results in an industry full of young ventures with a large demand for external capital and external technology expertise.

The paper is structured as follows. First, in a theoretical part we discuss relevant aspects when defining an INV and present some key elements linked to the understanding of resource access in form of funding and technology development. We then describe the empirical methods and the data material. Next, we present our analysis of the eight case studies and discuss how our findings contribute to knowledge related to the research questions and the existing BG/INV definitions.

Theoretical background

Definitions of International New Ventures and Born Global firms

The research on INVs and BGs has been fragmented with regard to defining the phenomenon (Cesinger, Fink, Madsen, & Kraus, 2012; Svensson & Payan, 2009) but most authors seem to agree that the core characteristics of the phenomenon are: 1) speed, 2) degree, and 3) scope of internationalization (Zahra & George, 2002).

The first studies aiming to define the INV/BG phenomenon in the 90's were originally initiated from two different research traditions, entrepreneurship and international business (IB). Inspired by the IB literature, Knight and Cavusgil (1996, p.11) suggested that born global firms should be defined as *"..small, technology-oriented companies that operate in international markets from the earliest days of their establishment*". This definition focuses on all types of international operations of a new venture and not on sale per se, but later Knight (1997) incorporated sales as the most important criterion and defined a born global firm as a firm with at least 25 per cent of its sales internationally within three years after inception. This definition is exclusively focusing on firms that have products ready for sale within three years after inception, and it does not include any pre-sales activities. Considering the authors' origin in the IB literature, a focus on existing firms and mainly their international sales activities can be seen as natural.

The more entrepreneurship inspired studies of the phenomenon is exemplified by the widely used definition which sees an INV as "*a business organization that, from inception, seeks to derive significant competitive advantages from the use of resources and the sales of outputs in multiple countries*" (Oviatt and McDougall 1994, p. 49). In addition to sales, Oviatt & McDougall mention the possibility of having international sourcing activities. The definition includes "sales of outputs" and “use of resources”, but the meaning of the latter is somewhat uncertain. When elaborating on the definition, Oviatt and McDougall comment that: *“The distinguishing feature of these start-ups is that their origins are international as demonstrated by observable and significant commitments of resources (e.g. material, people, financing, time) in more than one nation”* (Oviatt and McDougall 1994, p. 49). This could imply that the term “use of resources” points to the commitment of the INV’s own employees, money or time to be able to sell “outputs in multiple countries”. However, the authors also state that ”*some ventures actively coordinate the transformation of resources from many parts of the world into outputs that are sold wherever they are most highly valued”* (Oviatt and McDougall 1994, p. 57). Further, they describe ‘Global Start-ups’ as ventures that “..*not only respond to globalizing markets, but also proactively act on opportunities to acquire resources and sell outputs wherever in the world they have the greatest value*” (Oviatt and McDougall 1994, p. 59). These quotes do demonstrate attention to international sourcing activities, but it is not obvious how pre-sale access to international resources is included as a distinguishing feature of INVs.

Several of the cases presented by Oviatt & McDougall (1994) do have substantial international funding activities, though. The case company LASA had received “European” funding, about IXI they write: “*Funding for the venture was from the United Kingdom, Germany, Austria and Japan*”, and about Momenta Corporation; ”*funding is received from Taiwan, Singapore, Europe, and the United States*”. This shows that, when conceptualizing the phenomenon, access to resources through international activities was considered a relevant INV feature by Oviatt and McDougall (1994), even though the widely used definition does not explicitly include access to international resources. As previously stated, international activities related to sourcing have to a large extent been neglected in empirical studies, even though for example Jones (2001) showed that the earliest international activities could be related to sourcing.

In industries with long technology development periods such as the biotechnology industry (Hewerdine & Welch, 2013) and the marine energy industry, it may be of vital importance to gain access to international funding and technology in interaction with international R&D partners before the firm has developed a commercial product. Hence, firms within industries with significant time used for technology development may have been excluded from empirical studies of BGs/INVs simply because of the sometimes quite narrow definitions discussed above. These firms could have been classified as non-INVs, even though they are highly international from inception. In this paper we examine the access and use of international funding and technology partnerships of such firms.

Funding sources in the pre-commercial phase

In the INV literature, the access to financial resources is defined as a key challenge for early internationalization (Coviello & Munro, 1997; Løvdal & Neumann, 2011; Rennie, 1993), and earlier studies have demonstrated that when small firms are developing technology, sufficient financial resources in combination with access to external knowledge are critical (Jones, 2001; Kuemmerle, 2002). The challenge of accessing funding is likely to be an even greater hurdle for ventures in the pre-commercial phases still focusing on technology development without any income from sales. Actually, few studies have focused on how new ventures may access funding across national borders.

To examine this question we need to consider the characteristics of different funding sources and investigate to what extent they could be relevant for new ventures in a pre-sales phase. The different sources of funding we present below are venture capital firms, informal investors, public funding and larger corporations.

Venture capital (VC) firms usually invest in start-up or later phases (Clercq, Fried, Lehtonen, & Sapienza, 2006) which make them an unlikely financial source for pre-commercial new ventures in the marine energy industry because of the high uncertainty of technological success combined with high capital demands and the long expected time frames until exit.

Informal investors or *business angels* are private individuals who offer their own equity as risk capital to unlisted companies where they have no formal or family-related connections (Moen, Sørheim, & Erikson, 2008). Studies have shown that informal investors have a higher emphasis on the entrepreneur than VC firms (Mason & Stark, 2004) and are most likely to invest in close geographical proximity of their home or work (Harrison, Mason, & Robson, 2010). Further, they invest at an earlier stage than VCs and other financial institutions including during the pre-commercial and start-up phase (Moen et al., 2008; Reitan & Sørheim, 2000), and have usually a lower investment capacity than VC's (Clercq et al., 2006). We expect that informal investors can be an important local financial source in the early technology development stage for pre-commercial INVs, but less likely to act as an international funding source.

Public financial support or soft funding of new technology-based ventures is widespread internationally (Maula, Murray, & Jääskeläinen, 2007) and important in the firm's early R&D- and "feasibility stage". Small scale grants are usually handed out by local public agencies, while larger grants are handed out on the regional, national or international level. Holmberg, Andersson et al. (2011) show that for marine energy companies, the levels of soft funding and public support schemes are very different between nations because of the individual national policies and the nation's general economic level (Holmberg, Andersson, Bolund, & Strandanger, 2011). Some public grants demand local presence and activities by the companies, and there are indications that access to funding is so important that pre-commercial companies in fact are willing to change their management structure or relocate activity between countries in order to be in a more favourable position for receiving public funding as described by Løvdal and Neumann (2011).

Corporate funding is regarded as larger corporations investing in younger and smaller ventures. Large corporations usually have higher funding capabilities than other private investors because they could possess high amounts of capital since they do not have the same portfolio pressure and required rate of return (Katila, Rosenberger, & Eisenhardt, 2008). This implies that large firms have more reasons to invest than only sheer profits, and the most common reasons are access to new technology or foothold in new markets (Benson & Ziedonis, 2009; Schildt, Maula, & Keil, 2005; Van de Vrande & Vanhaverbeke, 2013). For a pre-commercial venture, a corporate investment is attractive as it can involve both considerable funding and access to critical resources such as networks, manufacturing and technology expertise (Katila et al., 2008; Maula, Autio, & Murray, 2005). The future global market opportunities and possibilities to get hold of new technology make pre-commercial firms attractive investment cases for both national and international corporations. However, even with its advantages, we do not know how many new ventures that get access to corporate funding or the international element of such funding.

A brief look at possible funding alternatives points toward an interesting situation. The most likely funding is public technology development support. In order to get such soft funding, there will normally be requirements of local presence in some form. The implication is that if for example a Norwegian firm sources public funding in other countries, then it most likely has to locate at least some of its activities in that country. As a consequence, the firms may establish local alliances, establish subsidiaries or move the entire operations even before they have reached the sales phase. Additional complexity is added with regard to the possibility of funding related to EU support and EU technology development schemes, in principle they may reduce the importance of geographical location and regional/national presence.

Technology development and technology partnerships

Due to their newness, new ventures have limited internal resources and networks which leads to a lack of credibility among partners, suppliers, policymakers and customers (Oviatt & McDougall, 1994; Rennie, 1993), and furthermore their smallness gives them a shortage of skilled human resources

(Madsen & Servais, 1997). These challenges are likely to be even greater for pre-commercial ventures in the marine energy industry where the process of developing technology from the initial idea to a fully commercial solution is complex, expensive and time-demanding. The marine energy industry experiences an ongoing technology battle (Løvdal & Neumann, 2011; Renewable-UK, 2012) where there is a diversified technology development process among firms and lack of a 'dominant design' (Anderson & Tushman, 1990). Thus, all the different technologies in the industry lead to few standard solutions available when supplementing the main technological system with additional subsystems. Even if a new venture might have a unique technological solution, it rarely possesses all expertise within the organization to also manage the complexity needed to verify the idea, conduct experiments in laboratory and larger scale tests in ocean tanks and in ocean environment. This complexity creates a demand for specialized competencies that are not necessarily available locally or within an existing network (Katila et al., 2008). These circumstances give new ventures in this industry motivation and need for being involved with external technology partners (Løvdal & Aspelund, 2011) which can provide access to knowledge.

Attractive technology partners are often larger and more established firms with experience from commercialization and industrialization of related technologies. A technology partnership could for instance involve close interaction among firm personnel (Eisenhardt & Schoonhoven, 1996; Schildt et al., 2005), access to physical facilities such as laboratories and R&D facilities or be focused on testing, developing or integrating external technologies (Van de Vrande & Vanhaverbeke, 2013) as subsystems of the ventures' total system. Such close technology partnerships can boost the capabilities and innovativeness of small firms (Nieto & Santamaría, 2010) and have been found to be beneficial for the smaller firm's development (Villanueva, Van de Ven, & Sapienza, 2012), but it also gains the external firm in form of access to new technology, increasing sales or as a reference in a new market.

In general, the ability to access both financial resources and external knowledge resources is influenced by the firms' technology potential, the human resources within the firm and their ability to attract and cooperate with credible partners. Earlier studies have shown that new technology-based firms are often actively involved in partnerships (Miles, Preece, & Baetz, 1999) and studies on INVs have shown that these ventures can successfully engage in both interfirm collaboration and international partnerships with larger companies to access external resources (Gabrielsson & Manek Kirpalani, 2004; Madsen & Servais, 1997; Phillips McDougall, Shane, & Oviatt, 1994).

Because of the long and complex technology development period we expect the pre-commercial companies to be dependent on external resources for developing their technology and commercializing their solution. We do expect that both domestic and international large corporations are relevant technology partners. We also expect that new firms with an international orientation will be more likely to find the right technology partners. The reason is that the technological resources needed by the case companies is probably rare and may be provided only by a few companies. In addition, few large companies have the ambition of seeking a strategic position within the industry and are willing to allocate the required resources to engage in the long technology development processes in an emerging industry.

Overall, we expect a significant international orientation among the case firms related to funding and technology partnerships in the pre-sales phase. This is based on the fact that demand for wave and tidal energy solutions is assumed to be very global in nature, but also on the assumption that the firms in this emerging industry have a huge need for capital as well as specialized competencies from partners which may be difficult to find in local or national environments. Based on the case studies, we will be able to describe and analyse these issues more in detail and contribute with regard to what Løvdal and Neumann (2011) and Rasmussen et al (2012) describe as an understudied part of the INV literature.

Methodology

The firm is the unit of analysis and each firm in the study represents an individual case study, but since the study as a whole covers eight different firms it can be described as a multiple-case design (Eisenhardt & Graebner, 2007; Yin, 2009). To increase the credibility and reliability of the study (Yin, 2009), we have triangulated data from interviews with secondary sources of evidence and we have cross-referenced our findings. Our primary sources are eight personal interviews with company representatives, while secondary sources are national and international industry reports, industry conferences in Norway and Scotland, company and industry web sites, news articles and interviews with representatives from public organizations and industry organizations. The interviews were conducted late autumn 2011 and were based on a semi-structured questionnaire addressing key themes and challenges for companies in a pre-commercial and emerging industry. Each interview lasted about one hour. Specifically, the themes were about the basic product idea and company background, technology development, partnerships and collaboration, funding, international activities and policy frameworks. The interviewees had all a deep insight and long connection to the firm and were either founder, CEO or in charge of business development. The interviewees decided location and date of the interview as many of the companies were occupied with projects. Three of the interviews were conducted via telephone. However, the procedure was the same as for the face-to-face interviews and two members of the researcher group participated in each interview.

In order to be qualified as an appropriate case study object, the firms had to be active Norwegian companies with full-time employees aiming to develop devices for harnessing marine energy via tidal currents or ocean wave. Via search on industry web pages, contact with industry organizations and public agencies, we identified 16 companies which were contacted and asked to participate in the study. Four of the firms turned out to have limited activity with no full-time employees, and four did not respond to our inquiries or did not want to participate with the time limits presented. The remaining eight companies fulfilled the selection criteria and were willing to participate

We transcribed all the interviews and then carried out a within-case analysis of each company where we produced a 3-5 pages summary of each company based on the interviews and additional information from external sources. These case summaries were sent to the interviewees for approval and to ensure construct validity. We then performed a cross-case analysis (Eisenhardt, 1989) by selecting categories as funding sources and technology partnerships which were relevant for our research questions, and by designing tables to analyse and identify common and differential factors.

The case companies

Table 1 shows some general descriptive characteristics of the case companies. To maintain anonymity, the firms are presented with their industry – wave or tidal – and numbers ranging from 1 to 4. We see that all the eight case companies are relatively young, founded between 1997 and 2010, with sizes varying between 1 to 30 full time employees.

Table 1: General descriptive characteristics of the cases

Firms	Established	Employees	Idea developer
Tidal1	2008	1 full time, 6 people engaged in various part-time work	Independent entrepreneur
Tidal2	2004	4 full time, 5-10 people engaged in various part-time work	Independent entrepreneur
Tidal3	1997	25-30 full time employees	Spin-off from utility company
Tidal4	2009	2 full time	Independent entrepreneur
Wave1	2010	3 full time	Independent serial entrepreneur

Wave2	2002	10 in-house, 15 included partners etc.	Developed within existing organization
Wave3	2010	10 part time. Hiring competence from R&D institutions	Originally a spin-off idea from existing company in the '80s. Revitalized in 2010 by existing owners.
Wave4	2006	3 full time, 3 part-time	Independent serial entrepreneur

Findings

In this section, we show the results of our case-based empirical analysis. To do this, we describe each single case firm briefly, with a main focus on their international activities.

Tidal1 has had limited formalized international activity during its first two years since inception. Their funding sources were basically the founder's own capital, small local business grants and national public grants of £80 000. The firm is not involved in any formal technology partnerships, but collaborates on a more ad hoc basis with specific local engineering companies. The reason may be that it is still in its quite early development stage in which exploration may be more important than exploitation of external competences. In collaboration with a Belgian firm, Tidal1 actively participates in a two-year long EU sponsored project from 2012. In this project, EU-based SMEs and research institutions are collaborating on developing Tidal1's technology. The firm has only tested small scale pilots in local facilities, but plans to conduct future larger scale pilot tests and demonstration tests in ocean environments in the UK.

Tidal2 has received funding through several local and regional grants (£270 000) and has also many small private investors. More importantly, Tidal2 has received direct technology development funding (£1.1 million) and technology expertise through two different EU projects, and it has also funded some of the development costs through its Austrian partner who has contributed in technology development partly in exchange of shares in Tidal2. The strategic partnership with their Austrian partner was formalized in 2007/08 and was Tidal2's first major international activity. This collaboration helped in legitimating Tidal2's technology and has worked as a door-opener towards R&D partners and industrial collaboration national and international technology partners. Through their technology partners, Tidal2 receives valuable complementary knowledge on system components and design which are crucial for making their technological solution viable. For example, their Austrian partner is a world leading ski lift producer with expertise within wire systems and has dedicated technical personnel to collaborate closely with Tidal2 continuously from 2008, while their Dutch composite materials partner has provided hands-on knowledge on the mooring system that the tidal energy device needs. Tidal2 is aiming for a global market and are looking for more partners internationally, but plan to conduct a full scale test of the system in Norway from 2013.

Tidal3 had until 2007 primarily all activities in Norway receiving £1.3 million in public grants for start-up phase, R&D and scale pilot testing. In the same period, their Norwegian owners, the parent company, two regional investments companies and a multinational energy company, injected £7 million into the company. In 2007, Tidal3 started collaborating with a Scottish firm who invested £1.1 million, and together they established a joint venture in Scotland. More recently, an Austrian hydropower firm has become majority shareholder. In 2007, Tidal3 also received £4.3 million in public funding from Scottish authorities for conducting tests of their full scale pilot in Scotland. Since they still had a head office in Norway with control of the intellectual property they also received a total of £0.9 million in Norwegian public funding from 2007 to 2010.

Together with their international corporate owners, external partners have given Tidal3 valuable technology competences. Norwegian partners have provided complementary knowledge on sub-system components, operations and maintenance, while international partners have applied experience and core technology from the hydro industry, but also complementary knowledge such as integration of the technology in a power producing system. The company relocated to the UK in 2007 because of better opportunities for both funding and finding partners, and state that it would have been impossible to come this far if they had stayed in Norway.

Tidal4 has had limited international formal engagement during its first three years of existence, but the firm had an international orientation right from inception when identifying companies which could supply them with special solutions. For example, when developing their turbine they searched globally for leading expertise on hydro turbines and got in touch with a Canadian turbine specialist from whom they received tailor-made services on an ad hoc supplier basis. Their funding comes from the two founders themselves combined with £220 000 in Norwegian public grants so far, and they have only some informal collaboration with local industry firms. In fact, Tidal4 considered to move to the UK right after inception because of better public support systems and infrastructure there, but decided not to because of personal preferences and priorities among the key personnel. Today, they regret they did not move the company to the UK in the beginning, and estimate this decision has potentially cost them two years of development.

Wave1 was established only a little more than one year before data collection. The firm has received a total of £70 000 through start-up grants, and a larger Norwegian energy company has financed the company’s first tank tests. Otherwise, they have no technology partners and are not engaged in any international activities, but are highly aware of international opportunities as for instance production in China and more lucrative support schemes and potential market in the UK.

Wave2 has had an international focus from inception through their multi-industry parent firm and network. The company has had basic funding from their parent firm and received public grants of at least £0.3 million in Norway. The firm has many international partners as key suppliers on R&D, other wave companies and industrial firms with complementary specific expertise. One example is a partnership with a UK-based engineering firm who specializes in structures in harsh physical environments. This partner has helped Wave2 reduce costs in specific areas including manufacturing, deployment and installation of their device. As a leader of a partner consortium consisting of two other industry firms and a university, Wave2 has received £2.4 million from UK authorities for conducting pilot tests there in 2012. Wave2 has collaboration with both Swedish and UK-based wave companies on non-critical areas of technology development like operative matters, practical experience and exchange of supplier experience. The company's viewpoint is different than the other case companies who consider the benefit of cooperating with competitors as minimal because of too varied technological challenges. Wave2 has already moved part of their operations to the UK because of market size and support schemes, and will consider moving more activities out of Norway.

Wave3 is a joint venture between a Norwegian multi-industry firm and a Norwegian hydropower firm. Since its establishment a little more than a year before data collection, the owners have provided the company with both funding as well as complementary knowledge. The company has only received small scale public grants for technology testing and has had only limited collaboration with potential Norwegian technology partners. So far, they have had very little international activity, but state that they are likely to perform pilot tests abroad in the future.

Wave4 has had an international orientation from the start, and received funding already two years after inception from a Swedish investment company wholly owned by a business angel. It is now the company's majority shareholder. In addition, the founder has injected more equity into the company and it has also received public grants in Norway of £1.4 million. Wave4 distinguish itself from the other case companies with a more distinct focus on close cooperation with end-customers such as utility companies or authorities in targeted global markets instead of partnering with international technology developers. This strategy has been a door-opener to dialogue and potential funding from the respective customers' national agencies. Wave4 has been granted £155 000 from New Zealand authorities for setting up a pilot plant there in 2014. The firm also signed a license agreement with a Turkish energy company in 2009, and is working closely with Spanish partners.

Wave4 has also a completely different view on the end-market than the other case companies. Instead of focusing on the larger future markets as for instance the UK and the US, the firm has targeted a niche market consisting of off-grid island communities globally where electricity is expensive because the only electricity sources are for example expensive diesel generators.

Discussion

This section analyzes the research questions by conducting a cross-case analysis. Below we will discuss the contribution and implication of our findings with regard to the extent and scope of international funding and technology partnerships in the firms as well as the questions of why and how they engage (or do not engage) in international activities in these areas. Finally, we discuss the implications of our study with regard to the definition of the INV phenomenon.

The extent and scope of international funding and technology partnership

Table 2 presents the case companies' international funding sources and their technology partnerships. As it appears, most of them have some international activities in this pre-sales phase. There are, however, quite large variations among the firms.

Table 2: International funding and technology partnerships among the case companies

	International funding resources	**Technology partnerships**	**Technology partnership focus**
Tidal1	Active participation in product development project sponsored by EU	No strategic technology partnership, but collaboration with specific local engineering companies.	Partners contribute with concept development and small scale testing. Seeking for investors and strategic partners.
Tidal2	Important funding through two EU projects (£1.1 million). Funding through international technology firms who receive shares and/or production contracts as payment.	Strategic technology partnership with Austrian wire producer. Technology collaboration also with Dutch, British, Finnish, Swiss, Canadian and Norwegian partners. Cooperate with universities in Norway and internationally, first tank test conducted in the UK in 2006.	The different industrial partners contribute with expertise on their specific field both in planning and testing phases. Partners receive shares or exclusivity.
Tidal3	Received £1.1 million in equity from Scottish renewable energy firm in 2007. Austrian hydropower firm who now are majority shareholder invested unknown amount in 2010 and 2012. Funding from UK authorities for full scale pilot testing in 2007 (£4.3 million).	Many national and international technology partners. Established Joint Venture in Scotland together with Scottish firm. Different owners (Austrian, Scottish and Norwegian firms) have contributed with technology development.	Owners provide both competence and secure financing. Partners have applied experience and expertise from oil & gas subsea industry and hydro industry. Needed international complementary expertise to move further towards commercialization.

Tidal4		No strategic technology partnership. More informal collaboration with industry firms.	Looking for the best solutions globally. For example Canadian turbine manufacturer designed tailor-made solutions for them.
Wave1		No strategic technology partnership. Testing scale models at Norwegian university.	Need strategic partners to further develop the company.
Wave2	R&D-grants and support from EU-programs. Received £2,4 million out of a £7,4 mill project (together with 3 partners) from UK authorities.	Has many established technology partners, also within mother-firm. Close relationships with key suppliers and some other international wave energy firms. Cooperation with R&D institutions in Norway, Belgium, Portugal and the UK.	Has cooperation with Swedish wave company where they exchange knowledge and test facilities. Strategic partnership with UK 'hostile environment' engineering firm which have complementary expertise.
Wave3		Joint Venture between hydropower and multi-industry firms. Owners have complementary knowledge and are industrial partners for the technology developers. Some collaboration with other Norwegian firms. Large network through parent organizations.	Dialogue with R&D institutions, some exchange of experiences with competitors.
Wave4	Swedish private investor is majority shareholder and has invested £3.2 million. Acquired £155.000 in public funding from New Zealand authorities through customer-collaboration.	No strategic technology partnership. Collaborates with end-customers in New Zealand, Spain and Turkey.	Collaborates with international end-customers in niche markets as off-grid island communities. Collaboration increases local presence and give technology legitimacy both in Norway and abroad.

If we summarize the findings from table 2, we see that half of the case companies (Tidal2, Tidal3, Wave2 and Wave4) have a strong international orientation towards funding resources already in the pre-commercial phase. These international funding sources vary from a private investment company (Wave4), larger technology firms (Tidal2 and Tidal3) and public grants (Tidal3, Wave2 and Wave4). Further, three of the case companies have formal technology partnerships (Tidal2, Tidal3 and Wave2), all with international partners, while Wave4 has signed formal collaboration agreements with international end-customers.

Tidal1 has weaker international activities since it is limited to funding through an EU sponsored technology development project, but participation in this project gives a potential of meeting and collaborating with international firms and research institutions. The remaining three firms (Tidal4, Wave1 and Wave4) do not have international activities, but all of them have ideas and plans of international activities pertaining to testing, production, funding, or other activities. In general these firms are quite young, often established 1-2 years before data collection. This may be a reason why they have not yet realized their ideas about international activities. In fact, these companies have not received any external private funding and do not have any formal technology partnership at all with the exception of Wave3 which is a joint venture between two Norwegian industry firms.

Table 2 also shows that most of the case companies' international activities are within Europe, and especially from the north and west of Europe, with an exception for Wave4 which has partners and activities also in Oceania and Tidal2's Canadian partner.

Figure 1 below, illustrates that case companies with significant international activity regarding funding or technology partnerships, are also highly internationally oriented on the other dimension. In principle, a company could search for funding outside of Norway, but conduct technology development within Norway. Or it can use an opposite approach with funding from Norwegian sources only and technology development internationally, but none of these situations are observed among the case companies. It seems to be so that technology development arrangements are connected to funding. For example, companies establish partnerships with local firms to be in a better position for receiving public grants for technology development and pilot testing in other countries, or technology partners receives shares or invest own equity into the venture. In addition, some of the interviewees state that international technology partnership agreements increase the credibility of the firm and are positive in discussions with both potential investors and when applying for public grants at home and abroad.

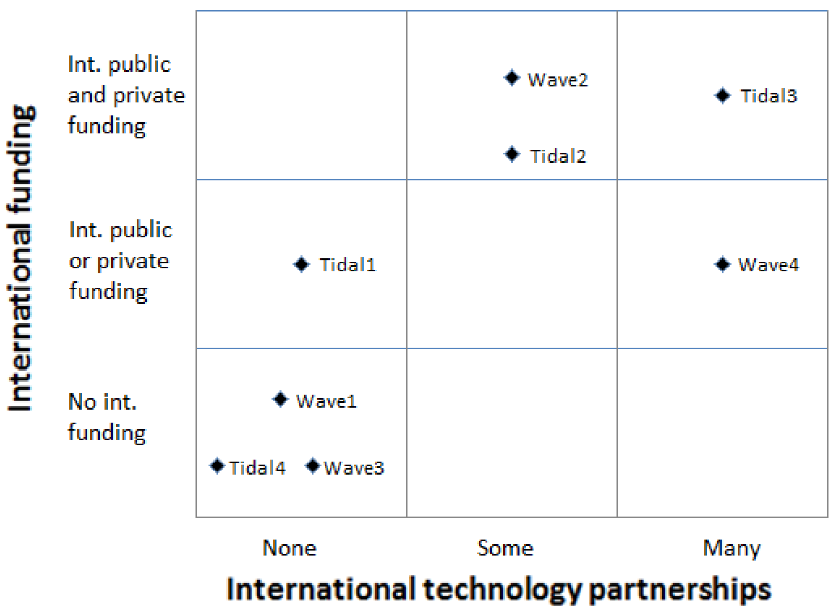

Figure 1: The degree of internationalization among the case companies

Another striking result is the willingness of some companies to relocate activity even in the pre-sales phase. Tidal3 and Wave2 have moved all or some operational parts of the company to the UK as a consequence of better funding possibilities and ongoing partnerships with firms located there, Tidal4 evaluates moving the company to the UK because of better funding possibilities, infrastructure and potential partners while China is a likely production location for Wave1 because of the considerable lower production costs. This reflects the degree of international orientation of the companies as well as the importance of funding and technology development in these early phases.

Why and how do these firms engage in international activities?

The case companies report access to capital and technology development to be their greatest challenges. All of the companies have been able to receive initial public grants from Norwegian authorities, but this is not enough for the companies when they plan to conduct larger and more expensive pilot tests. Norway is Europe's largest producer of hydropower and a net exporter of electricity in a normal year, which gives Norway low electricity prices and low demand for new renewable energy. This situation in combination with a booming oil and gas industry creates limited interest from both Norwegian authorities and industrial firms to invest in new renewable energy as the marine energy industry. This fact combined with more generous funding schemes internationally, especially in the UK, is the companies' main motivation for searching for funding internationally. The reason for searching international funding is thus triggered by a push as well as a pull effect.

A consequence of the search for international funding is that companies look for international technology partners as well as attempts to establish local presence in foreign countries that offer attractive funding schemes. This is clearly demonstrated in case firms that have established presence and/or engaged in technology partnerships abroad. Except for partnerships driven by funding considerations, there is a clear pattern, especially among the most internationally oriented case companies, that they aim for partnerships to get access to critical external technological resources. Here, international technology partners are very attractive because of access to unique technology resources which very few companies possess even internationally (for example Tidal2's partnership with an Austrian wire producer or Wave3's British "harsh environment" engineering firm) and because of small interest in marine energy among Norwegian energy and manufacturing firms.

The international technology partnerships have been differently organized by the case companies, partly depending on the need for funding in combination with specialized technologies. Tidal2's closest partner has dedicated personnel collaborating continuously with them on technology development. This has been financed on the partner's expense, but also by offering shares in Tidal2 to the partner. However, the partner's main motivation might be that their firm is likely to be a big supplier of parts to the final system if Tidal2 successfully commercializes their solution. Wave3 has set up a technology developing consortium with their partners aiming to conduct a pilot test in rough ocean environments. This solution has given them access to grants from UK authorities, but also more dedicated efforts from their partners in the development and testing of their pilot device. Tidal3 on the other hand, established a joint venture with a Scottish firm to continue the technology development in Scotland, which further lead to major international private investments and public grants to the company. In general, it seems as results are more profound when the case companies enter into partnerships with higher commitment from both partners. Such partnerships require a long-term orientation and clear targets, but also high degrees of trust among the partners.

Wave4 collaborates with end-customers in targeted markets, but not so much with technology partners which is different than the other case firms who have entered technology partnerships before targeting potential end-customers. An example is a project Wave4 has launched together with a New Zealand based energy company where they aim to deliver wave power to an off-grid island community through a pilot in 2013 and scale up later. This collaboration has so far resulted in international funding in form of a grant from New Zealand authorities and has, in addition, given Wave4 insight into more diverse customer needs and behaviour.

Based on this, we can divide the case companies into three groups;

1. *Technology and funding driven internationalizers* (Tidal2, Tidal3 and Wave2)
   These companies have ventured internationally mainly to enhance their technology development process either by finding technology partners, by seeking access to more funding, or a combination of the two.
2. *Market-driven internationalizers* (Wave4)
   This company is different from the other case companies because it clearly separates the marine energy market into segments where it targets a niche market. Its main international focus has been to approach end-customers in these potential markets globally.
3. *No or limited internationalization* (Tidal1, Tidal4, Wave1 and Wave3)
   These ventures are so far only thinking about international engagement. This might be because they have not been able (Tidal4 and Wave1) or willing (Wave3) to access international resources. These are the youngest among the case companies with least progress in technology development and thus lesser need for technological expertise which

might explain their limited international activities so far. However, as table 3 below shows, Tidal2, Wave2 and Wave4 had already extensive international activities at the same age.

The motivations and actual forms of international activities are thus quite diverse among the case companies, but the overall findings suggest that an international engagement has been beneficial for case companies in group 1 and 2 for accessing more funding and for strengthening their technology development. For firms in group 3, a likely outcome is longer development time and an even longer way to a commercial market illustrated by Tidal4's estimation that the decision to not internationalize had cost them potentially two years of development. This raises the question why not companies in group 3 are more focused on international engagement, especially since there are high visibility among competitors' international funding sources and partnerships, and strong factors that push (limited funding) and pull (beneficial policy regimes, higher abundance of funding and technology partners) companies abroad.

Early international sourcing activities are neglected in the INV literature

The findings show that already before having a commercial product ready, four out of eight case companies have a high international activity level and the case descriptions show that all see the end-market as international or global. Four ventures (Tidal2, Tidal3, Wave2 and Wave4) have received international funding from a variety of sources (private investors and investment companies, larger firms and research grants) originating from New Zealand, Sweden, Austria and the UK. Important partners are located in the Netherlands, Sweden, the UK, Finland, Austria, Spain, Turkey, New Zealand and Canada. In fact, most formal technology partnership agreements are with international partners. Further, table 3 below shows that three out of the four internationalizing companies were three years or younger when doing their first major international activity.

Table 3: First international activity and age for selected case companies

Case companies	First international activity	Age of first international activity	Degree of international activities	Scope of international activities
Tidal2	Formal technology partnership with Austrian wire producer in 2007/08	3 years	Many international technology partners International private funding	Technology partners are from Europe and Canada
Tidal3	International technology partners and owners in 2007	10 years	Many international technology partners	Technology partners and owners are from several European countries

			International private and public funding	
Wave2	Have had international partners from inception through their mother firm and network from 2002	From inception	Many international technology partners International public funding	Technology partners are mainly from Northern and Western Europe
Wave4	Swedish investors in 2008, Turkish license agreement in 2009.	2 years (but international focus from inception)	Some international partners International public and private funding	Partners are from New Zealand, Turkey and Spain. Investor from Sweden

Even though we have found case companies that are international basically from inception (speed), with a large extent of funding from international sources and many technology development partners (degree) from all over Europe, Canada and New Zealand (scope), they would still not be characterized as a BG according to Knight's definition (1997) since they are in a pre-sales phase. Our study therefore strongly supports the inclusion of other aspects than sales when categorizing firms according to their degree of internationalization. The mindset of management in these firms is clearly international and their early international activities will definitely provide the grounds for subsequent international sales of their solutions. In order to understand their international activities in for example 2020 it is important to understand their initial internationalization process.

Oviatt and McDougall's (1994, p. 49) definition of an INV, on the other hand, does include sourcing side activities. In relation to the case companies in this study their definition is therefore much more relevant. As mentioned earlier, however, Oviatt and McDougall did not clearly state how the term "*use of resources"* in their definition should be interpreted. Based on our study we suggest defining an INV as *"a business organization that, from inception, seeks to derive significant competitive advantages from the* ***access to resources,*** *use of resources and/or planned or actual sales of outputs in multiple countries*". This definition stresses that obtaining access to international resources (for example funding) is an important issue for firms in industries such as the marine energy industry. In order to capture the special features of INVs we argue that it is necessary to include international sourcing activities even in early development stages because these might be key elements in order to understand also the further development of these newly established and internationally oriented firms.

Implications and future research avenues

This study has concentrated on an understudied part of the INV literature and has shown that new ventures could have extensive international activities on the sourcing side where they acquire critical resources as capital from international private and public funding sources and technology competence through active involvement with international partners.

For business managers, this article shows that a new venture's international engagement already in the pre-sales phase could increase the possibility of accessing financial and technological resources. The observed link between international technology partners and international funding for the pre-commercial companies could imply that companies able to attract international partners, either in technology development or as future customers, increase their funding possibilities.

This study also demonstrates how companies can exploit international opportunities created by different policy regimes already in a pre-commercial phase. For policy makers, this shows that there is a risk of companies moving their activities to other countries before they start to generate income, even though they have received early stage soft funding from local authorities. Such implications should be carefully considered when creating policy regimes for emerging industries.

For research, our study has demonstrated that INVs could exist also in the pre-sales phases and that the INV definition presented by Oviatt & McDougall (1994, p. 49) should also consider international sourcing side activities in order to understand further development of new and internationally oriented ventures. Further, our results have shown that the international activities before first sale could be extensive, and for industries with long technology development periods such activities could be of vital importance for securing access to crucial resources. Based on the findings in this article, it would be interesting to further investigate why some new ventures choose to internationalize early in the pre-sales phases while others are more reluctant to do so. What do such strategic choices mean for the companies in the long run, and which group of companies will succeed best? Another promising research area would be how the international activities in the pre-sales phases affect future internationalization pattern and future sales in international markets. Especially, how the different international funding sources have impact on the future internationalization progress of the firms. Another promising area could be the dynamics and coherence of funding and technology development in the pre-commercial phases for ventures which are capital intensive and have long technology development periods.

A clear limitation is that this study only consists of Norwegian companies from the marine energy industry. It would be interesting to see if similar results are to be found among companies in other countries and industries, and specifically within countries with more attractive policy regimes than Norway as for example the UK. Similar studies of international activities among companies in other emerging industries or industries with long technology development periods would also be interesting, and especially with larger quantitative surveys to investigate the extent of the phenomenon.

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Article 2:

The funding of new technology firms in a pre-commercial industry – the role of smart capital

ARTICLE 2

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The funding of new technology firms in a pre-commercial industry – the role of smart capital

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In this article, we focus on how investors add value, in addition to finances, to resource-constrained young technology companies in a pre-commercial and capital-intensive industry. Based on a review of the entrepreneurial finance literature, we group investors' value-added contributions into four categories: 'Business development', 'Technology development', 'Investor's outreach' and 'Legitimacy'. We build our study on six case studies of firms in the pre-commercial and emerging marine energy industry. Our case companies have received investments from business angels (BAs), venture capital (VC) firms and larger corporations (CVCs). We observed that the contributions from the investors clearly differ and that CVC investors appear to be especially important as their involvement helps increase young technology firms' credibility, which could be a crucial factor in pre-commercial and emerging industries. Overall, by engaging 'smart capital', a company can move from a situation of true uncertainty to one of manageable risk.

Keywords: smart capital; investor value-added; venture capital; CVC; BA; new technology-based firms; pre-commercial industry; emerging industry; marine energy

Introduction

New technology-based firms are important participants in the growth of new industries and in the renewal of existing industries because of their introduction of new innovative technology. In addition to being innovative, these firms are also characterised by being growth-oriented and having limited internal resources. Developing and commercialising innovative and com-plex technology is challenging, time-consuming and expensive, and resource-constrained new ventures require external funding to get past the technology development phase.

In addition to financial capital, new technology-based firms also require input in areas such as industry-specific expertise, contacts with potential customers, technology competence, knowledge of foreign markets or expertise in business administration. These are areas where investors can contribute, and previous research has studied the post-investment contribution provided by equity players such as independent venture capital (VC) firms (Busenitz, Fiet, and Moesel 2004;

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Abstract

In this article, we focus on how investors add value, in addition to finances, to resource-constrained young technology companies in a pre-commercial and capital-intensive industry. Based on a review of the entrepreneurial finance literature, we group investors' value-added contributions into four categories: *'Business development', 'Technology development', 'Investor's outreach'* and '*Legitimacy'.* We build our study on six case studies of firms in the pre-commercial and emerging marine energy industry. Our case companies have received investments from business angels (BAs), venture capitalists (VCs) and larger corporations (CVCs). We observed that the contributions from the investors clearly differ and that CVC investors appear to be especially important as their involvement help increase young technology firms' credibility, which could be a crucial factor in pre-commercial and emerging industries. Overall, by engaging 'smart capital', a company can move from a situation of true uncertainty to one of manageable risk.

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Introduction

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In addition to financial capital, new technology-based firms also require input in areas such as industry-specific expertise, contacts with potential customers, technology competence, knowledge of foreign markets, or expertise in business administration. These are areas where investors can contribute, and previous research has studied the post-investment contribution provided by equity players such as independent venture capital firms (Busenitz, Fiet, & Moesel, 2004; Gorman & Sahlman, 1989; Sapienza, 1992; Sapienza, Manigart, & Vermeir, 1996), business angels (Madill, Haines, & Riding, 2005; Politis, 2008; Sætre, 2003) and corporate venture capital (Gompers & Lerner, 2000; Maula, 2001; Maula, Autio, & Murray, 2005; Zu Knyphausen-Aufseß, 2005). Overall, previous studies have shown that investors can contribute by active involvement in their portfolio companies and that the post-investment contribution by the different investor types is somewhat overlapping. However, relatively few studies include different types of investors (Luukkonen, Deschryvere, & Bertoni, 2013), and Large and Muegge (2007) state that new insights can be reached by examining how different types of investors add value to new ventures. Furthermore, most studies on VCs and CVCs have investigated the investors' value-added contributions from the investors' perspective (Park & Steensma, 2012), and there is an over-representation of studies using cross-sectional data that do not really illuminate how investors add value to the ventures (Sørheim, 2012). There are also relatively few studies exploring the emergence of industries (Forbes & Kirsch, 2011), and a study of different investors' involvement and value-added input into new technology firms in an emerging and pre-commercial industry has, to our knowledge, not been done before.

The goal of this paper is to explore different investors' involvement and non-financial value-added into new technology-based firms in a pre-commercial industry. More precisely, we present six case studies of Nordic companies in the marine energy industry (wave and tidal energy) that intend to develop devices to harness energy from ocean waves and tides.

The marine energy industry is an emerging and pre-commercial industry. This means that there exist no commercially viable solutions yet, that there is still a battle between different technology designs, that the value-chain is undeveloped and that there is a lack of industry standards. Furthermore, the majority of the firms in the industry are small and independent firms which in addition to facing an expensive and complex technology development process, also must struggle with the industry's limited credibility among potential public and private stakeholders due to being a pre-commercial industry for 15-20 years. This results in an extensive demand for funding, technology competence and credibility among young firms in the industry, and even though the many uncertainties surrounding the emerging industry limits the interest of potential investors, there are still a wide variety of investor types investing in new firms in the industry. Our research questions are as follows:

- *What kind of contributions do different types of investors bring to the table besides funding?*
- *To what extent are the investors' post-investment contributions relevant for technology firms in a pre-commercial industry?*

To address these questions, we consider the characteristics of different investor types and investigate to what extent they are relevant to aspects that are critical to the development of new technology firms.

This study makes several contributions. First, we show how different investor types add non-financial value to young technology firms in a pre-commercial industry with high uncertainty in technology and market development. Second, we show that having larger and established firms as investors could give a legitimation effect that is crucial for young firms in a pre-commercial industry. Furthermore, our study is one of few studies who investigate the impact of investors' post-investment contributions from the entrepreneurs' perspective.

The paper is structured as follows: First, we briefly present the marine energy industry before we outline relevant theories of different investors' contributions to new technology-based firms. Then, we describe our methods and case studies before we discuss our findings and analysis. Finally, we conclude and suggest implications.

Frame of reference

The marine energy industry context

The marine energy industry comprises firms developing devices to harness energy from ocean waves and tides, and is an emerging, pre-commercial and global renewable energy industry. So far, no commercially viable technologies exists, but recently many full-scale tests have been performed, especially in the UK, which has been the industry leader for several years (Elliott, 2009). The industry is facing a ‘technology battle’ between a wide range of technological solutions, but no single design has yet become dominant among either wave or tidal energy developers.

The technology development process is a long and capital-intensive process demanding access to a wide range of technologies, and includes several rounds of pilot tests. The full-scale pilots include large physical structures, sometimes weighing hundreds of tons, and installing and operating them in harsh ocean environments leads to high costs for demonstration tests. The total costs of developing a project from concept verification to full-scale demonstration project are well beyond £10 m in addition to several years of testing and verification of the technology. Furthermore, as it is pre-commercial, the marine energy industry does not have a developed value chain and firms have to identify and engage potential suppliers and partners from other industries. This can be a challenge as the industry has limited credibility due to being in a pre-commercial phase for almost two decades.

In 2013, around 150-200 firms were developing marine energy technologies globally and earlier studies have found the majority of these to be small, young and highly international firms (Bjørgum, Moen, & Madsen, 2013; Løvdal & Aspelund, 2011) with limited financing possibilities from the private sector (Leete, Xu, & Wheeler, 2013). These financial limitations were strengthened by the financial crisis of 2008 and a slower progress in the industry than expected, which specifically made VC funding more difficult to receive. However, an increased commitment to the development of a marine energy industry from large nations as the UK and France has helped to maintain funding possibilities for firms in the industry. In fact, studies have found that £1 of public support has unlocked around £6 of private investments in the UK (Renewable-UK, 2012), and a major part of these private investments has been from larger corporations that demand long-term commitment from governments before investing (Renewable-UK, 2012). This pattern, where there are many new firms with a broad set of technologies in the beginning and where larger firms enter as the industry moves towards commercialisation, is recognisable from other emerging capital-intensive industries like biotechnology (Hopkins, Crane, Nightingale, & Baden-Fuller, 2013).

The combination of complex and capital-intensive technology development and many independent start-ups, results in a large demand for external funding, additional technology expertise and legitimacy. These firms face extraordinarily high uncertainty and do not have the ability to fund their development and growth entirely from internal or public sources (Rasmussen & Sørheim, 2012). To address this uncertainty, these firms could seek the involvement of investors who contribute with smart capital, i.e., investors contributing not only with resources related to funding (Mason & Harrison, 2003). Experienced investors can bring a wide range of business skills and resources as general business insight, and more importantly specific industry knowledge, networks and experience (Cressy & Olofsson, 1997; Lindstrom & Olofsson, 2001; Mason & Harrison, 2003). The most common external funding sources are business angels, venture capitalists and corporate venture capital. To examine how investors are involved and how they contribute, we now consider the characteristics of the different funding sources and how they are expected to act as providers of smart capital.

Different capital sources and their post-investment contributions

In this study, *Informal investors,* or *business angels (BAs),* are considered to be private individuals who offer their own equity as risk capital to unlisted companies in which they have no formal or family-related connections (Moen, Sørheim, & Erikson, 2008). As a financing source, BAs often invest in new technology ventures in the seed, start-up or early stage, filling the gap between founders, family and friends on one side and VC funds on the other (Harrison & Mason, 2000). BAs can represent 'smart capital', using their business experience and networks from earlier careers to play a vital role in their portfolio companies' development and growth (Mason, 2007). Furthermore, the resource acquisition role of BAs is quite important for resource-constrained new ventures to be able to overcome the internal lack of resources and their networking activities can support the early development and growth of new and small firms (Mason, 2007) and help obtain additional funding (Sørheim, 2005). Previous research emphasizes that BAs have a role as internal resource providers, especially when it comes to general business development although this vary across the investor population (Politis, 2008). Their external contribution is to a large extent related to their networking role. However, the ability to act as resource providers could be constrained because of the pre-commercial nature of the industry covered in this study. Generally, the number of BAs with direct experience from a specific pre-commercial industry is most likely limited, and this could reduce the potential for their value-adding network effects. Other limitations are the capital requirements for these firms, which are very high compared with other attractive industries like ICT and web start-ups.

Venture capital (VC) firms are run by professional management companies that invest from a fund consisting of capital from private persons and/or institutions, for example, banks and pension funds. VC firms are not interested in funding basic research; they generally invest in start-up or later phases (De Clercq, Fried, Lehtonen, & Sapienza, 2006) when both technological and market risks are lower. VCs are also hands-on investors who utilise their business competence, experience and extensive networks so that their portfolio companies can access and build strategic alliances and connect with customers (Berg-Utby, Sørheim, & Widding, 2007; Busenitz et al., 2004).

Several studies have been performed on VCs' value-added activities, and although the findings are contradictory regarding the effects of a VC investment on a portfolio firm's performance, the majority of the studies conclude that the effect is positive (Sørheim, 2012). Gorman and Sahlman (1989) categorise the value-added services of VCs as follows: "(1) help to obtain additional financing, (2) strategic planning, (3) management recruitment, (4) operational planning, (5) introductions to potential customers and suppliers, and (6) resolving compensation issues (Gorman & Sahlman, 1989). In a review of 20 peer-reviewed articles on the non-financial, value-adding activities of VCs, Large and Muegge (2007) identify eight different value-adding types of input provided by VCs. They make a clear distinction between internal and external activities. External activities are; (1) *legitimation* and (2) *outreach*, while examples of internal activities are; (1) *recruitment*, (2) *strategy*, (3) *consultation*, and (4) *operation.*

From the perspective of a young, technology-developing venture in a pre-commercial industry, the most likely contributions from VCs may be help with additional funding, general business management and strategy, and the reputational effect of having a VC investment. This reputational effect can be important in attracting other investors (De Clercq et al., 2006) or critical in persuading potential stakeholders to be involved in the venture's future development. Furthermore, Sapienza, Manigart, and Vermeir (1996) found that VC investors with experience from the venture's industry added significantly more value than VCs without such relevant industry experience, and this is also likely to be valid regarding VCs with experience within the marine energy industry.

On the other hand, recent studies questions the role of VCs in emerging and capital-intensive industries since the investment time frame and the uncertainty of the development of these industries is not suited for VC investment (Hopkins et al., 2013; Leete et al., 2013). This can be explained by VCs looking for returns that are not very realistic when investing in firms facing long and capital-intensive technology development (Mazzucato, 2013). Another important point is the uncertainty related to the political framework for the firms in this industry. This means that the business models for operations is still under development and this is unattractive for VC firms with a maximum of 10-year horizon on each fund.

Corporate venture capital (CVC) is established corporations investing in younger and smaller firms. Larger corporations are generally focusing their investments on securing strategic benefits by accessing new technology or get foothold in new markets (Benson and Ziedonis, 2009; Van de Vrande and Vanhaverbeke, 2012). This strategic investment focus gives large corporations a low portfolio pressure and a low required rate of return in the short-term compared to VCs, and makes it possible for them to invest higher amounts to create larger benefits in the long-term.

Companies in related established industries will often choose to take a minority position in start-ups in a pre-commercial industry. They want to have a “listening post” in order to prepare for future development and be able to take a position as technology and markets mature. This means that CVCs may invest in early-stage firms developing pioneering technologies that may not otherwise have been able to obtain funding from VCs (Chemmanur & Loutskina, 2009). This difference in investment motives between CVCs and VCs also affect how they add value to their portfolio companies. Maula, Autio and Murray (2005) showed that there is a complementarity and that VCs are mostly involved in “nurturing” the venture (e.g. expertise on company formation and early growth), whereas CVCs provide technological support and a strengthening of the commercial credibility of the firm. This strengthening of a new firm’s credibility is an important effect of having a CVC investment and may be considered a ‘stamp of approval’ of the new technology. Furthermore, this effect may be a door opener towards potential stakeholders such as investors, public agencies and other industry players.

From the portfolio companies point of view, a corporate investment is attractive because it can provide both considerable funding and access to critical resources such as networks, manufacturing and technology expertise (Maula et al., 2005). Moreover, Park and Steensma (2012) observed that CVC investments were most beneficial to new ventures that required specialised as opposed to generic complementary assets although other investors may have had better offerings. They also found that CVC funding was most beneficial to ventures operating in “uncertain environments” (Park & Steensma, 2012). Maula, Autio and Murray (2003) argued that complementary aspects of the business of the CVC investor and the portfolio firm are a prerequisite for knowledge sharing and successful relations (Maula, Autio, & Murray, 2003). Furthermore, Gompers and Lerner (2000) found that the performance of CVC’s portfolio companies was most successful when there existed similarities, a ‘strategic fit’ and a ‘knowledge fit’, between the corporation’s and the venture’s line of business. This means that CVCs have an important role as an internal resource provider especially when it comes to technology development and can play a crucial role as external resource provider when there is a good ‘fit’ between the CVC and the portfolio company.

Based on our review of investors’ value-added contributions, we have identified four categories in which investors can add non-financial value to pre-commercial technology firms in an emerging industry. As we can see from table 1, *‘Business development’* is a broad category comprising value-added activities such as strategic planning, operational planning and involvement, mandating and mentoring of the entrepreneur which our literature review have found central for

VCs (De Clercq et al., 2006; Gorman & Sahlman, 1989; Large & Muegge, 2007), and to some extent also for BAs (Politis, 2008) and CVCs (Maula et al., 2005). Furthermore, the '*Technology development'* category is relevant when evaluating CVCs' value-added to technology ventures (Maula et al., 2005) and it is especially important for firms in a pre-commercial industry with very long and complex technology development processes. The category *'Investor's outreach'* comprises value-added activities such as help to obtain additional funding and introductions to potential customers and partners which earlier research has found to be central contributions for both VCs (Gorman & Sahlman, 1989) and BAs (Mason, 2007). The fourth category, *'Legitimacy',* is built on the investors' potential value-added reputational effects identified by earlier research (De Clercq et al., 2006; Large & Muegge, 2007) which are very important for young firms in a pre-commercial emerging industry. In addition, in line with Large and Muegge (2007), we separate our framework into investors' internally oriented and externally oriented value-added activities.

Table 1: Overview of the four value-added categories and the different investors' contributions as identified in the literature

	Category	**Description**	**BA**	**VC**	**CVC**
Investor's internal value-added contributions	*Business development*	Hands-on contribution in strategy, business administration and organisational development.	Low to moderate	Moderate to high	Low to moderate
	Technology development	Relevant technology skills, competence in testing and quality control, access to technology or technical facilities such as laboratories, testing sites and equipment.	Low	Low	Moderate to high
Investor's external value-added contributions	*Investor's outreach*	Actively providing direct access to different stakeholders such as financial sources, public agencies and industry partners.	Low to high	Moderate to high	Low to high
	Legitimacy	A passive contribution in which the perceptions of the investor's brand and image help strengthen the new venture's credibility and reputation to external stakeholders.	Low	Low to moderate	Moderate to high

In addition to describing the four different categories, table 1 also compares the input of the different investor types in the four categories based on our findings in the literature. Table 1 shows that we can expect to identify a somewhat complementary relation between the value-added contributions of CVCs and of VCs in which CVCs have moderate to high value-added in the areas in which VCs have low value-added ('Technology development' and 'Legitimacy'). Regarding BAs, we can expect to see many of the same contributions as for VCs although perhaps less valuable contributions overall. In addition to the differences in table 1, other important complementary aspects to consider are the timing and the amount of capital provided by the investor groups (De Clercq et al., 2006). The timing of the investment is especially important because BAs are expected to be the most active investors in early-stage technology ventures (Harrison & Mason, 2000), and such investments could turn out to be critical for the ventures to survive the first years and develop further. Based on the case studies, we can analyse and discuss the role of different investor types for new technology firms in a pre-commercial industry from the entrepreneurs' perspective, and thereby contribute new insights within both the literature on investors' value-added contributions (Large & Muegge, 2007; Luukkonen et al., 2013; Sørheim, 2012) and the literature on emerging industries (Forbes & Kirsch, 2011).

Methodology

The study is exploratory in nature and seeks to understand how different investors support new technology-based firms in the marine energy industry to commercialise their technology. The firm is the unit of analysis, and each firm in the study represents an individual case study. Because the study as a whole covers six different firms, it can be described as a multiple-case design (Eisenhardt, 1989; Yin, 2009). Two researchers conducted the interviews in the autumn of 2012. The interviews lasted approximately one hour and were based on a semi-structured format to allow free-flowing conversation and in-depth inquiry into topics that emerged during the interview. More specifically, the interviews focused on relevant themes from the entrepreneurial finance literature such as ownership structure, pre-investment phase, investor engagement and contributions, investor relationship and future financing. The interviewees all had great insight and long involvement in the firm, being founders and/or CEOs. In order to increase the credibility and reliability of the study, we have triangulated interview data with data from secondary sources (Yin, 2009). Our secondary sources include the case companies' websites, news articles, press releases, industry websites, industry reports, international industry-specific conferences (U.S., Scandinavia and Scotland), publicly available consent applications and investor websites. The secondary sources were used to gain deeper knowledge and understanding of the industry, to identify case companies and prepare for interviewing them, and to validate as much information as possible after the interviews.

By combining the different sources of information, an in-depth description of the funding process was obtained. From this in-depth description, we identified characteristics that were central in the process of interaction with the investors. Following our research questions, we needed case companies that were likely to have a relatively rich history of private investments and experience with different investor types. To find such case companies, we had the selection criteria that companies should have received external funding, should have full-time employees and have conducted, or being close to conduct, prototype tests in ocean environment (a technological milestone). We also chose companies from the Nordic countries for this study because this is one of the leading marine energy regions. This also means that the included companies are relevant to compare in the sense that they are in the same industry and at the same stage in their life-cycle. Using industry web pages, contact with industry organisations and public agencies, we identified 15 companies that fulfilled the selection criteria. From these, we contacted eight companies, of which six were willing to participate.

We transcribed all the interviews and then performed a within-case analysis of each company in which we produced a 7-10-page summary of each company based on the interviews and additional information from external sources. These case summaries were sent to the interviewees for approval and to ensure construct validity. This is of vital importance in order to avoid misunderstandings related to the content in the case studies. We then designed tables related to the research questions and performed a cross-case analysis (Eisenhardt, 1989; Miles & Huberman, 1994) by analysing and identifying common and differential factors between the individual cases. This analysis uncovered the different patterns regarding investors' internal and external value-added contributions.

The case companies

In Table 2, we see that the case companies are in a technology development phase, and all but Langlee have tested scale devices of their technology in ocean environments. Some of the technological solutions are unlike anything else in the industry. For example, Flumill's tidal energy device is constructed of composite materials and based on the principle of 'The screw of Archimedes'. Minesto is developing underwater wings to generate power from the tides, whereas Floating Power Plant (FPP) is the first in the world with a floating hybrid device that generates electricity to the grid from both ocean waves and wind. Furthermore, Table 2 also illustrates the size of the devices and the extensive rounds of testing they need in the technology development process. When commenting when they believe they will deliver their first commercial marine energy project, the case companies' answers were between 2015 and 2019. In table 2, we also see that all the companies are quite small with between 4 and 30 regular employees.

Table 2: General description of the case companies

Firm	Founded	Employees	Technology	Full scale unit	Technology development progress
Floating Power Plant, Denmark	2004	4 regular, 15 including partners and board	Hybrid wind & wave energy	-6 MW wave & 6 MW wind -1,800 tons -80 m wide	Continuous ocean tests of 1:2 scale device (37 m wide, weighing 320 tons) since 2008. This has been grid connected since 2012.
Flumill, Norway	2002 (2009)	5 regular, around 15 with partners	Tidal energy	-2,1 MW -160 tons -18x48 m	Built a tank to prove the concept in 2010. In 2012, a 1:2 scale pilot was tow tested and grid connected during ocean testing at the Orkney Islands. In 2013, Flumill began developing a full scale demonstration plant with 2-4 devices.
Langlee, Norway	2006	5	Wave energy	-50 kW -70 tons -15x15 m	Several tank tests. Full scale ocean testing is planned in the Canary Islands in 2014.
Minesto, Sweden	2007	Around 25	Tidal energy	-0,5 MW -7 tons -12 m wing	In 2012, a grid connected 1:10 scale pilot was tested. Since late 2012, a 1:4 scale pilot has been continuously tested in the waters of Northern Ireland.
Seabased, Sweden	2001	Around 30	Wave energy	-100 kW -12 tons -4 m buoy	Extensive ocean testing of their device since 2006. Currently installing the first 42 units (25 kW) of a 10 MW park which is supposed to be finished by 2015.
Wello, Finland	2008	8	Wave energy	-0,5 MW -220 tons -30 m	Tested first a 1:18 scale pilot in ocean conditions in 2011. Since 2012, Wello has been testing a full scale, grid connected prototype at the Orkney Islands.

In table 3 below, we see that the case companies have many different types of investors with different investment motivations. These perceived motivations are based on the interviews with the case companies, the investors' webpages or the investors' annual reports. Even though the motivations are not directly stated by the investors, they give some insight into why the different investors are involved in new firms in this pre-commercial renewable energy industry.

Table 3: Description of the investors and their perceived investment motivations

	Types of investors	Perceived investment motivations
Floating Power Plant (FPP)	- Five BAs on the board represent majority of shareholders (about 100 passive small investors). - Regional public VC fund with renewable energy focus has invested £1.2 m. - Multinational energy firm has invested around £0.5 m for around 7 % of the shares.. - Joint venture (JV) partner in the U.S. has invested capital.	- Major BAs: Purely financial motive - Regional public VC fund: Invest in renewable energy projects within its region. - Multinational energy firm: Possible future customer of FPP. Want to aid the firm so that if the technology comes through, they have a high knowledge of it. - US JV partner: This firm is specialized in bringing renewable energy ideas to the commercial marketplace.
Flumill	- Founder owns 14%. - Local composite company invested, took charge of project management and re-started Flumill in 2009. Owns 25%. - Scottish energy consultant firm with no other major investments invested in 2010. Owns 16%. - Renewable energy company with professional investment owns 43% and has injected over £4 m since 2010.	- Local composite company: Strongly believes in the idea and the future market. Will be supplier of core parts to the device. - Scottish energy consultant firm: Believed in the idea's potential and wanted equity share to motivate efforts to develop the company. - Renewable energy company: Does usually not invest in such early-stage companies, but have a regional engagement and a focus on renewable energy combined with a belief that they can actively help Flumill.
Langlee	- Swedish BA has invested £2.5 m and is majority owner. - Two minor BAs	- Main BA: BA knew the CEO from earlier business relationships and had faith in the CEO and Langlee's product.
Minesto	- Idea originates from Swedish multinational focusing on other industries. Has still a minor share. - Two private investment funds (VC1 and VC2) are the biggest owners. - The local university has a small stake - VC firm that specialised in buying portfolios has a small owner share. - There are 5-10 minor BAs.	- Swedish MNC: Believe in the idea and want to support it further. - VC1: Focusing on new ventures within clean tech and life science that "give a good return and at the same time provides global and environmental benefits". - VC2: Long-term perspective on its investments with focus on regional firms. - Portfolio VC: Financial motive, bought a part of MNC's spin-off portfolio.
Seabased	- Majority of shares are held by the company's two founders - <u>Other investors are:</u> - Private investors on the board and other private persons as the CEO - Swedish pension fund - Japanese invested £1.03 million for 1.46% of the shares. - Dutch electric cables firm - The university	- BAs: A mix of personal and financial motives - Swedish pension fund: Long-term investor with primarily financial motive. - Japanese MNC: MNC has a strategy to invest in new renewable energy technology. It sees their investment as a strategic positioning in an emerging global industry. - Dutch multinational electric cables firm: Collaborating with the University, interested in new renewable energy and possible future supplier.
Wello	- The BA invested a small amount in early phase - A VC fund focusing on renewable energy is lead investor. - Finnish public VC fund is co-investor The VC and the public VC has over two investment rounds injected around £7 m including an unknown amount in governmental grants.	- BA: Investor knew founder and believed in the potential of the idea. Both personal and financial motive. - VC fund: Focusing on renewable energy. Partners have a lot of experience from energy and electricity industries. - Public VC: Invests in early stage Finnish technology firms with international growth potential. The goal is to cover shortcomings in the market and supplement private investors.

Analysis and discussion

The purpose of this study was to investigate different types of investors' post-investment contributions among young technology firms in a pre-commercial industry. In this section we present the overall findings from the cases regarding the different types of investors' involvement and their value-added contributions. We then present and discuss the findings related to the research questions from the introduction.

What kind of contributions do different types of investors bring to the table besides funding?

Table 4 below gives a description of investor involvements that have added value to the case companies. We observe that four of the six case companies have BAs as their first investors (the exceptions being Flumill and Minesto, whose BAs came in later), which underlines how important BAs are as providers of capital in the critical first phase, even for start-ups in a pre-commercial industry with long time horizons. All of the case companies have experience with having, or trying to attract, VCs as investors. For future financing, some of the firms emphasize that they will try to stay away from VCs because of VCs' focus on accelerated development plans, which they consider to be too short-term in this type of industry. Furthermore, the case companies report extensive efforts towards raising more capital from investors, especially VCs as they are the most visible ones. For example, one of the companies contacted almost 70 and met up with around 30 investors, mostly VCs, in 2012 with none of these meetings leading to an investment proposal.

Table 4: The investors' external and internal value-added contributions in the case companies

	Investors' internal value-added contributions	**Investors' external value-added contributions**
Floating Power Plant (FPP)	Three of the BAs use 20%-80% of their time to help run the company. Energy company contributes with knowledge of electrical infrastructure, public applications, and technical support on testing site. JV partner is actively developing two sites in the U.S.	The BAs have actively provided connections that have led to technology partnerships, and funding from VC fund and informal investors. The BAs are working to establish a consortium with industrial and financial partners to conduct full-scale testing in France, Spain or the UK. JV partner searches for co-financing of U.S. projects.
Flumill	The composite company has been in charge of technology development and management since 2009. This investor designed and built a specific testing tank at its own facility to verify the technology. The CVC investor has two people active on the board and is consulted on technical and financial issues on an ad hoc basis. The Scottish investor was CEO 2010-12 and is now developing a new application of the technology.	The composite company has good industrial network, especially within subsea industry. The Scottish investor was recruited through personal relations with the composite company. It has good knowledge of the UK energy market and a well-established network. The CVC investor provides connections to the electrical components industry. Its reputation nationally has improved Flumill's credibility among external stakeholders.
Langlee	The majority-owning BA has little involvement in business development; however, one of the other BAs	Investors have provided some industry contacts. Majority-owning BA helped Langlee securing a loan it needed when struggling with public funding procedures.

	is on the board. From 2012, annual strategy meetings with investors are occurring.	
Minesto	The two VC funds are actively engaged in business development, both formally by the board, and informally. The CVC investor is engaged in the board, and is also working on technological issues and provides access to physical facilities.	VC1 has provided international industrial connections and provided a financial advisor who succeeded in gathering additional funding from both BAs and VC2. The buyout fund provided a link to an important international technology partner. The internationally renowned brand of the CVC investor has been crucial as a door-opener, especially in the start-up phase.
Seabased	BAs are engaged in business development and strategy through the board. The pension fund contributes with expertise in financial management. The Dutch CVC is also a supplier of electric cables for Seabased; however, these roles are kept separate.	The BAs provide a global personal network towards funding sources and industry actors such as the Japanese CVC investor and the Swedish pension fund. The CVC has a global presence and will be in charge of financing and project management of Seabased's future global projects. The CVC is a globally renowned firm, giving credibility to Seabased internationally.
Wello	BA and two representatives from the VC fund are on the board. The VC representatives are also informally involved on a day-to-day basis in strategic issues.	BA provided connection to the VC fund. Two of Wello's main suppliers have been provided by the VC fund. One of these is a portfolio firm of the VC that it used a lot of effort to persuade to collaborate with Wello. Wello experience a good reputational effect by having VC investors when negotiating with suppliers.

In table 5 below, we have grouped the different investors' contributions in the four value-added categories presented in the theoretical section through a subjective comparison of the case companies. Our assessment comprises the amount of input from the investors, how important the case companies regard this input, and the potential outcomes of the different contributions. Based on these inputs, we rank the investors' contributions in table 5 by giving them a 'scoring' between three and zero stars. Here, (***) reflects a strong impact which means that the investor's contributions within a category have been central in the development of the firm and that these contributions are difficult to acquire from alternative sources. (**) is given when the investor's contributions have had considerable, but less significant impact on the firm's development, while (*) is given when the investor's contributions have had a minor positive impact within the specific category. In table 4 above, we have briefly illustrated many of the value-added activities of the investors, but we will further show some examples to give a better understanding on how we have assessed the different investor contributions. For example, 'Flumill's Scottish Informal investor' with experience and network in the UK energy sector has had a strong impact (***) in *'Business development'.* His contributions through being the company CEO for two years, a board member since 2010 and in charge of their UK subsidiary since 2011, have been crucial for the development of the firm and made it easy for Flumill to be present in the UK market. 'Wello's Finnish public VC' on the other hand, is assessed as having had a minor impact (*) in '*Business development'* with its inputs mainly as a member of the board.

In the '*Technology development*' *category* 'FPP`s Energy company' has made a considerable impact (**) as it has been central in the full-scale ocean testing of the device through helping FPP with environmental consents and bureaucracy, handled 95% of the electrical infrastructure (grid connecting and cabling), and has also given FPP access to their expertise in operations and maintenance during a two-year testing period. Within the *'Legitimacy'* category, several of the case companies state that having VCs and/or larger firms as investors makes it easier to approach external firms or interact with government agencies. For example, 'Flumill's local CVC' has made a strong impact (***) within the '*Legitimacy'* category by being a highly reputed investor and renewable energy producer in Norway. When evaluating their consent for a demonstration plant and a £6 m government grant, Flumill's CTO stated: *"Without (…) as a majority, a big shareholder, we would have never gotten the consent and the grant because that gave the company the strength we needed*". For Minesto, the global brand of their CVC investor has made a strong impact (***) on their credibility and helped open doors in Sweden and the UK right from establishment. 'FPP`s energy company' on the other hand, is evaluated to only have given a minor impact (*) within the '*Legitimacy'* category. This is because the investor wants to keep its involvement in FPP unofficial, which creates limitations on how much FPP can gain credibility by being associated with the investor.

Table 5 illustrates that the case companies' investors have contributed within all the different value-added categories but also that the three investor types have made different contributions. It appears that a majority of the BAs have made most impact within *'Investor's outreach'*, whereas the VCs overall make the strongest impact within both *'Investor's outreach'* and *'Business development*. Consistent with earlier research (De Clercq et al., 2006; Politis, 2008) VCs and BAs appear to be mainly involved within the same categories, but with VCs having a slightly more significant contribution since their involvement have more impact within '*Legitimacy'*. The input from the CVCs is completely different because they have provided the most important contributions within *'Technology development'* and *'Legitimacy'*.

Table 5: An assessment of the investors' value added in the different categories.

	Investors' internal value- added contributions		**Investors' external value-added contributions**	
	Business development and strategy	Technology development	Investor's outreach	Legitimacy
Informal Investors				
Flumill's Scottish Informal investor	***	*	*	
FPP's American JV partner	*		*	*
FPP's active private investors	**		***	
Langlee's main business angel			*	*
Langlee's smaller BAs	*			
Minesto's private investors			*	
Seabased's private investors	*		*	
Wello's BA	*		**	
VCs				
Seabased's pension fund	*			*
Wello's VC	**		**	**
Minesto's buyout fund			*	*
Minesto's 1st VC	**		**	*
Minesto's 2nd VC	**		**	*
FPP's local public VC				*
Wello's Finnish public VC	*		*	*
CVCs				
Flumill's local SME	***	***	**	
Flumill's local CVC	**	*	**	***
FPP's energy company		**		*
Minesto's CVC	*	**		***
Seabased's Japanese CVC			**	***
Seabased's Dutch CVC		*		*

Note: * reflects a minor impact, ** considerable impact, and *** reflects a strong impact. The grey cells show where the individual investor has its most valuable input.

To what extent are the investors' post-investment contributions relevant for technology firms in a pre-commercial industry?

To identify the relevance of the investors' contributions, we elaborate on the most important contributions in each of the four categories.

Business development

In our study, all the different investor groups have value-added input in this category. As earlier studies have shown (De Clercq et al., 2006; Politis, 2008), the case companies regard the VCs' input to have the strongest impact in this category although many BAs also contribute to a certain extent. Overall in our study, the VC investors' personal skills and experience combined with their understanding of technology and business development are considered important However, few of the VCs' contributions are considered critical from the case companies' point of view.

Technology development

Consistent with earlier studies (Maula et al., 2005; Mäkelä & Maula, 2008), our findings show that active CVC investors can strengthen the ventures' technology development. For Flumill, the technology competence of its investors has had major importance, and FPP received valuable technological input on site-specific tasks and access to physical infrastructure from their CVC investor. Consistent with Park and Steensma (2012), the case companies in this study valued the CVCs' ability to contribute to specific technology development more than the CVCs' general technology competence. Conversely, it is difficult to identify how rare the knowledge provided by the CVC investors is, as it could alternatively be provided by collaborating with other technology firms. However, one of the intriguing findings from this paper is the lack of contribution from VCs and BAs on the technology development side. This can be explained by the pre-commercial nature of the industry, which makes it possible only for a very limited number of individuals to contribute with relevant technology competence, and also because BAs and VCs do not usually have technological motives behind their investments.

Investor's outreach

As in earlier studies (Large & Muegge, 2007; Maula et al., 2005; Politis, 2008), all the investor types were actively providing connections valuable to the case companies. This category is where the BAs add most value; but in our study the connections provided by VCs and CVCs have made larger contributions to the firms' development overall. However, the BAs have a varied range of involvement, which is highlighted by the active BAs of FPP whose involvement in acquiring additional funding and industry partners has been of major importance to FPP. Furthermore, as described by Sapienza, Manigart and Vermeir (1996), the investors with background from related industries such as 'Wello's VC' and 'Flumill's local CVC', have provided important industry-specific connections that would otherwise be difficult to acquire. For a young technology company, having investors who are actively working to raise additional funding or provide valuable connections could be decisive for the company's future.

Legitimacy

Having credible investors appears to be highly valuable to our case companies, and as described in de Clercq et al. (2006), it is particularly the CVC investors who help legitimise the new ventures as trustworthy players. This is illustrated by Minesto, whose multinational owner with a global brand made it easier for potential partners and investors to accept both the company and the technology in Minesto's crucial start-up phase. For Flumill, the investment by their CVC investor with a reputation as a solid long-term player in the national energy industry, was crucial when applying for and receiving a £6 m public grant to build a demonstration site. It is also interesting to notice that the CVCs are patient investors with long horizons on their investments in this pre-commercial industry. This can be explained by their motivation for doing the investment. The CVCs want to take part in and stimulate to the development of firms that might open new commercial opportunities (besides the financial investment in the particular firm).

Although the legitimacy effect is most significant for the companies with CVC investors, VC investors and even informal investors can also enhance a firm's credibility with certain stakeholders in our study. This can be illustrated by Langlee, whose £2.5 m investment from a BA had an important effect on soft funding because a credible investor believed in the technology's potential.

All in all, our findings indicate that for a new technology venture in a pre-commercial industry, the most important investor contributions are the external contributions in which the investors, either actively or passively, help attract new or strengthen previously existing resources. Moreover, one of the most intriguing findings of this study is that the contribution of the investors clearly differs. The investors appear to have complementary roles in bringing the companies from a pre-commercial to a commercial stage. It is also interesting to note that although the CVCs' contribution to technology development is important, the major benefit of having a CVC on board is that it adds legitimacy to a young technology firm. This legitimacy effect is of course important for any start-up firm in a capital-intensive industry, but will of course be of outmost importance in a capital-intensive pre-commercial industry. The legitimacy effect appears to be of vital importance to firms in emerging industries facing true uncertainty with regard to both technology development and the maturity of the market. By engaging "smart capital", the company can move from a situation of true uncertainty to a situation with manageable risk where firms are more likely to attract a broader group of investors.

Furthermore, we believe the findings in this study could be transferable to other pre-commercial and capital-intensive industries with limited financing and involvement of different investor types. This could for example be other new renewable energy industries (Mazzucato, 2013) or the development of biotechnology industries (Hopkins et al., 2013).

Limitations and further research

This study has an exploratory focus because little is known regarding the investors and investor involvement in pre-commercial emerging industries such as the marine energy industry. The exploratory nature of the study means that the number of cases is limited to six companies from the Nordic countries. With the limited number of cases, there will be a danger that the results are sensitive to the specific case selection. However, through meetings on conferences, conference presentations and company web pages, we have knowledge of most of the marine energy firms in the Nordic region and we argue that the findings in our cases could be transferable, but it would be interesting to see whether similar results can be observed among companies in other geographical contexts and industries. Additionally, there are limitations to consider when analysing the collected data because we only have data from the entrepreneurs' view of the entrepreneur-investor relationship. This means that the findings reflect the perceived value-added contributions from the entrepreneur's point of view. Future research should examine the relation from both the entrepreneur and investor perspectives. Furthermore, terms like "value-added" and "contribution" underline that the focus is on investors' positive involvement. Thus, there is a danger of overemphasizing the positive impact and neglecting the potential negative impact. Another potential bias in our study is that it only includes relatively successful young firms in the sense that they all still exist. Finally, there is a need for longitudinal studies with numerous cases to reveal the complete picture of the role of investors for new technology firms in emerging and pre-commercial industries.

This study has revealed intriguing findings related to the involvement of investors in the pre-commercial and emerging marine energy industry. However, the staging of capital and interplay between investors is understudied and needs further attention. More precisely, if different types of investors stage their investments differently in a pre–commercial industry. It is also likely that this affect the interplay between the investors involved. More studies on the use of specific resources from different investors', studies with larger samples, in other markets or industries and over time, will increase the understanding of the role of different investors in the development of new technology firms in pre-commercial and emerging industries. Additionally, the co-evolution of financial institutions and technology firms in emerging and capital-intensive industries is an interesting avenue for further research. Is it actually possible to develop these emerging industries without a parallel development of financial institutions focusing on the industry? And, what role should the government have when building these robust financial institutions?

Conclusion and implications

This article contributes to the understanding of investors' involvement in young technology firms in a pre-commercial industry. This is one of the first studies comparing involvement from different types of equity investors from the demand side (i.e. seen from the company's point of view). The study has investigated how different types of investors add value besides funding, and our results clearly show that there is a difference in various investors' value-added. BAs and VCs made their most important contributions in '*Business development*' and '*Investor's outreach'*, whereas CVCs' most important contributions are in *'Technology development'* and especially *'Legitimacy*'. However, the credibility and reputational effects created by having a CVC investment appear in this study to have the most impact on the development of resource-constrained new technology firms in a pre-commercial industry.

Furthermore, for new technology-based firms facing market and technology uncertainty, our results show the benefit of having complementary investors with different value-added input and investment timing. An attractive investor path for firms in the marine energy industry could be having active BAs and CVC investors in the earliest phases which could lower the uncertainty, and VCs and other CVCs later as the company and industry matures.

Our study suggests further that companies in this pre-commercial industry are too focused on attracting VC investors, and that established firms and CVCs may have a more relevant role than traditional VCs in developing emerging industries by early involvement in new technology-based firms. Public policy makers should consider this and implement mechanisms that make it easier and more attractive for new ventures and established firms to be introduced and work together.

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Article 3:

Configuration of supply chains in emerging industries: a multiple-case study in the wave-and-tidal energy industry

ARTICLE 3

Configuration of supply chains in emerging industries: a multiple-case study in the wave-and-tidal energy industry

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Abstract: Companies in emerging industries face particular challenges in configuring effective supply chains. In this paper, we build on transaction cost economics to explore how supply chains can be configured in emerging industries. We focus on two key aspects of supply chain configuration: the *make-or-buy* decision and the *strength of the ties* between a focal firm and its suppliers. We utilise a multiple-case study methodology, including seven start-up companies in the emerging wave-and-tidal energy industry. We propose three models for supply chain configuration in emerging industries – 'the market model', 'the ally model' and 'the maker model' – and discuss the circumstances in which each model is suitable.

Keywords: supply chain configuration; emerging industries; wave-and-tidal energy industry.

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Configuration of supply chains in emerging industries: a multiple-case study in the wave-and-tidal energy industry

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Abstract

Companies in emerging industries face particular challenges in configuring effective supply chains. In this paper, we build on transaction cost economics to explore how supply chains can be configured in emerging industries. We focus on two key aspects of supply chain configuration: the *make-or-buy* decision and the *strength of the ties* between a focal firm and its suppliers. We utilise a multiple-case study methodology, including seven start-up companies in the emerging wave-and-tidal energy industry. We propose three models for supply chain configuration in emerging industries —'The Market Model', 'The Ally Model' and 'The Maker Model'— and discuss the circumstances in which each model is suitable.

Keywords: Supply chain configuration, emerging industries, wave-and-tidal energy industry

Introduction

Emerging industries face particular challenges related to supply chain configuration and coordination (Kirkwood & Srai, 2011), and they are often dependent on established suppliers and market channels which are based in competing industries. Entrepreneurial ventures are common in emerging industries, and although these bring new and innovative technologies to the market, they often lack the contacts and partners that firms in mature industries have established over years of operation. This leads the new ventures to engage in unstructured searches for potential supply chain partners. While the need for research in this area is explicit (Baril, Harrington, & Srai, 2012; Forbes & Kirsch, 2011; Harrington, Srai, & Kirkwood, 2011), the availability of published empirically based papers remains limited and scattered. The objective of this paper is to explore supply chain configuration models for firms in emerging industries.

Emerging industries are new industries in the early stages of development (Low & Abrahamson, 1997). Firms enter emerging industries either as new firms or through diversification from other industries. Some emerging industries arise primarily through the entry of new, independent firms, such as the many 'dotcom' firms in the mid-1990s or the many biotechnology start-ups in the 1980s (Hopkins, Crane, Nightingale, & Baden-Fuller, 2013). In the early phases of industry creation, new firms need to search and reach out across industry borders in order to gain necessary knowledge, complementary assets, partners, suppliers and potential customers to develop their businesses (Doz, Santos, & Williamson, 2001). Firms attempting to develop a supply chain and engage with potential suppliers, customers and other stakeholders face challenges due to emerging industries' limited standards, limited numbers of renowned players, high market and technology risks and low external legitimacy due to limited track records (Aldrich & Fiol, 1994; Zimmerman & Zeitz, 2002).

The wave-and-tidal energy industry is one example of an emerging industry (Magagna et al., 2014). It is a pre-commercial industry comprising firms developing devices to harness energy from ocean waves and tides. Currently, the wave-and-tidal energy industry, and its special knowhow, is located in particular hot spots around the world, such as in countries around the North Sea. Earlier studies have found the industry to be characterised by small, young and highly international firms (Bjørgum, Moen, & Madsen, 2013; Løvdal & Aspelund, 2011). Such studies have also found that this industry faces a particular set of complicating factors. First, there is no dominant technological design, which leads to a broad variety of technical solutions (MacGillivray et al., 2013). Second, there are no current industry standards, which increases the difficulty of attracting investors and cost-effective insurance (Leete, Xu, & Wheeler, 2013; MacGillivray et al., 2013). Third, established players in the traditional energy sector have been reluctant to seek opportunities in the wave-and-tidal energy industry, which has left the market open to new and independent ventures (Bjørgum et al., 2013). Fourth, a special characteristic of this industry is the substantial size and weight of the technology, which often requires capital-intensive yard equipment (quay, cranes, etc.) and favours local manufacture close to installation due to high logistics costs and risks (Magagna et al., 2014). Finally—and, partly, as a result of the other characteristics—there are no established supply chain networks in the industry (Krohn et al., 2013). Therefore, the wave-and-tidal energy industry is a particularly interesting case to study the configuration of supply chains in emerging industries.

Configuring supply chains is a crucial activity that can determine a company's success or failure in emerging industries (Kirkwood & Srai, 2011). Despite their importance, methods for emerging industries to develop effective supply chain configurations are lacking (Baril et al., 2012). Through a multiple-case study of seven wave-and-tidal energy companies, we investigate which supply chain configurations are developed in each case and why. We focus on the first tier of the supply chains for the main structure of the devices (that is, we do not study the complete supply chain networks). Furthermore, we limit the analysis to two classic supply chain design parameters: the make-or-buy decision (Walker & Weber, 1984; Williamson, 1975) and the weak versus strong ties of supply chain relationships (Cooper, Lambert, & Pagh, 1997; Williamson, 1991).

We structure the paper as follows. In Section 2, we review transaction cost arguments for the make-or-buy decision and for the strong versus weak ties in supply chain relationships. These perspectives are then applied to examine the characteristics and context of the wave-and-tidal energy industry. In Section 3, we present our multiple-case research methodology. In Section 4, we present the details of the seven specific cases. In Section 5, we analyse the cases, present three models for supply chain configuration in emerging industries and discuss the conditions in which each model is suitable. In Section 6, we conclude, discuss limitations and suggest further research possibilities.

Literature review

The literature on supply chain network configuration has been primarily concerned with established firms in mature industries (e.g. Cheng, Farooq, & Johansen, 2011; Cheng, Farooq, & Johansen, 2015; Lambert & Cooper, 2000; Li, Sun, Gu, & Dong, 2007; Shi & Gregory, 1998; Zhang & Gregory, 2011). Although much of the literature is applicable to entrepreneurial firms in emerging industries, such industries also face a set of complicating factors and unique challenges that make supply chain configuration particularly difficult. The practical implication of these challenges has been that most companies attempting to scale their businesses in emerging industries develop their supply chains in unstructured patterns. Harrington et al. (2011, p. 8) argue that 'a lack of understanding of the entire value chain and its supporting supply network will see companies fail to exploit their potential as the industry matures'.

Two strategic questions are of particular importance: First, which processes should the firm provide itself, and which should it buy in the market? Second, with regard to parts sourced from external suppliers, what level of integration should the firm develop between itself and its suppliers?

The make-or-buy decision

The make-or-buy decision is fundamental to operations strategy and defines the scope of a business. Transaction cost economics (Coase, 1937; Williamson, 1975, 1985) provides theoretical arguments for when to organise economic activities in hierarchies (make) and when to organise them in markets (buy). It involves two assumptions—people are rational and people are opportunistic—which lead to transaction costs in a business relationship (Grover & Malhotra, 2003). Transaction costs include the costs of searching for vendors, administering the transaction, risk hedging, control and follow-up. In addition to transaction costs, companies also face production costs, which are the actual costs of producing the product or service. The decision to make or buy is based on a comparison of the total costs of the two alternatives. According to Williamson (1975, 1985), there are three factors that particularly impact the transaction costs: transaction frequency, transaction uncertainty and asset specificity.

Transaction frequency refers to how often a transaction is repeated. The traditional argument is that if a transaction occurs often, internal transaction costs are lower than the transaction costs of an external relationship (Williamson, 1985). Hence, high transaction frequency suggests a hierarchical organisation of economic activity.

Judging the *uncertainty* of a transaction involves considering the degree to which deliveries can be detailed and specified in contracts ('environmental uncertainty') and the degree to which actual deliveries can be measured and controlled ('behavioural uncertainty'). The traditional transaction cost argument is that high *environmental uncertainty* encourages hierarchical organisation (especially in the presence of transaction-specific assets) (Williamson, 1975). Similarly, when *behavioural uncertainty* is high (i.e. it is difficult to control whether actual deliveries comply with expected deliveries), transaction cost theory suggests a hierarchical organisation of economic activity. The argument is that firms have greater control over internal relations than they do over external relations.

Walker and Weber (1984) provide more nuanced advice regarding environmental uncertainty. They differentiate the following two types of environmental uncertainty: 'technological uncertainty' and 'volume uncertainty'. *Technological uncertainty* describes the difficulty in predicting technical requirements in the buyer-supplier relationship. In mature industries, researchers have argued that transaction cost theory suggests a market solution when technological uncertainty is high because such a solution allows the firm to shift faster to vendors with other technologies (Balakrishnan & Wernerfelt, 1986). *Volume uncertainty* describes the difficulty in predicting the demand of a product or service. When volume uncertainty is high, transaction cost theory suggests hierarchical solutions because the control of the supply chain is likely to reduce total production and transaction costs.

Asset specificity refers to the resources that are directly related to a transaction. High asset specificity means that a technology or resource has little value outside a specific business relationship. If the resources involved in producing the product or service are not easily deployed outside the specific transaction, then suppliers are likely to increase the transaction costs in order to hedge against risk. Moreover, suppliers' production costs are likely to be higher if they must invest in resources that cannot be employed in other transactions. Therefore, higher asset specificity encourages a hierarchical organisation of economic activity. Of the three factors which determine the transactions costs, asset specificity is regarded the most critical in make-or-buy decisions (e.g. David & Han, 2004; Shelanski & Klein, 1995; Williamson, 1985).

Level of integration

Despite being one of the most used, tested and confirmed theories in management literature, transaction cost theory is criticised for being under-socialised and mechanistic. Specifically, critics argue that traditional transaction cost arguments underestimate the value of trust and interpersonal relationships (e.g. Dubois, Hulthén, & Pedersen, 2004; Hill, 1990; Nooteboom, Berger, & Noorderhaven, 1997). Economists have replied to this critique by contending that social relations can also be modelled in terms of transaction costs. Transaction cost theory has, therefore, been expanded through an understanding of the strength of the ties in buyer-supplier relationships (Grover & Malhotra, 2003; Williamson, 1991), which allows differentiation between arms-length relationships (weak ties) and alliances (strong ties) in buyer-supplier relationships (Geyskens, Steenkamp, & Kumar, 2006; Hoyt & Huq, 2000; Williamson, 1991).

Alliances can be seen as hybrids of hierarchical organisations and market organisations (Geyskens et al., 2006; Nooteboom et al., 1997). The usual argument is that transaction costs can be significantly reduced by investing in trust and strong ties with suppliers (Dyer, 2002). In a buyer-supplier relationship, *high transaction frequency* and *high asset specificity* suggest that a tight relationship is the preferred choice precisely because transaction costs can be reduced. From a supply chain configuration perspective, Lambert and Cooper (2000) suggest that the suppliers of critical importance to a firm's operations (e.g. due to high asset specificity and/or transaction frequency) should be managed more closely than others. Furthermore, Wu and Ragatz (2010) suggest that close relationships foster joint learning in product development processes. Geyskens et al. (2006) find that higher levels of all three types of *transaction uncertainty* (i.e. 'behavioural', 'technological' and 'volume') tend to have the opposite effect and, furthermore, were all associated with arms-length buyer-supplier relationships. High uncertainty works against the development of tight relationships because actors hedge against the uncertainty by keeping alternative supply chain options open.

Supply chain configuration in the wave-and-tidal energy industry

In general, both production costs and transaction costs are high in the emerging wave-and-tidal energy industry. The fact that many of the firms in the industry are small, lack manufacturing resources and face complex technology development processes (Løvdal & Aspelund, 2011; MacGillivray et al., 2013) increases in-house production costs to a level where market solutions seem preferable. In addition, the industry's *low transaction frequencies* suggest that arms-length relationships (i.e. 'buy with weak links') may be the preferred solution. However, precisely because the industry is emerging, there is often a lack of market alternatives from which to choose, meaning that even established players have relatively high production costs. Consequently, alliances and in-house production facilities are often the more realistic options.

In particular, *technological uncertainty* is high in the emerging wave-and-tidal energy industry for numerous reasons. First, since it has existed in a pre-commercial phase for almost two decades, the industry has limited credibility. Second, the lack of a dominant design has led to a wide variety of technologies, with few industry standards or standardised solutions. This, in turn, has made potential suppliers cautious to engage in the industry because the customer base of new solutions might be inadequate (Magagna et al., 2014). Third, the size, weight and complexity of the technologies in this industry leave few options in the market, as these technologies requires expensive and specialised production assets. Finding and attracting potential alliance partners is, consequently, a challenge. The technology development process is long and capital-intensive, requiring several rounds of pilot tests and access to technological solutions from a wide range of industries. Full-scale pilots include large physical structures, sometimes weighing hundreds of tons, as well as installations and operations that occur in harsh ocean environments. These realities lead to high costs and high risks related to the technology development process. *High asset specificity* with *high uncertainty* encourages a hierarchical organisation of economic activity ('make'); however, if firms are not able to make their products themselves, *high asset specificity* and *high uncertainty* imply a tight buyer-supplier relationship (i.e. 'buy with tight links'). Finally, because *asset specificity* has been suggested to have the most influence on the make-or-buy decision (Walker & Weber, 1984; Williamson, 1985), a *low asset specificity* with *high uncertainty* favours a loose buyer-supplier relationship (i.e. 'buy with weak links') (Geyskens et al., 2006).

In summary, all types of buyer-supplier relationships have some merit in the wave-and-tidal energy industry. The transaction cost perspective offers competing arguments in favour of all three generic configurations (make, buy or ally). The 'best' solution depends on a case's particular situation. In this paper, we explore which configurations are the preferred choices under different conditions.

Method

We use a multiple-case study to explore supply chain configuration issues in the emerging wave-and-tidal energy industry. Case studies are particularly helpful when exploring the details of real-life and emerging phenomena (Eisenhardt & Graebner, 2007; Yin, 2009). To examine supply chain configuration in the emerging wave-and-tidal industry, we searched for case firms that either had conducted or were close to conducting prototype tests in ocean environments (a technological milestone for this industry). In other words, we wanted firms that had experience with making prototypes and cooperating with suppliers (i.e. 'Technology Readiness Level' 6–8). Furthermore, we chose companies from the UK and the Nordic countries because these are two of the leading wave-and-tidal energy regions. Table 1 presents details of the seven case companies included in the study. The chosen cases were small firms located in Denmark, Finland, Norway, Sweden and the UK.

Table 1 – Characteristics of the seven case companies.

Case firm	Founded	Number of employees (2013)	Technology	Country	Full-scale unit	Product development status (2014)
Floating Power Plant	2004	< 20	Hybrid wind and wave	Denmark	6 + 6 MW 1,800 tonnes 80 meters	Continuous ocean tests of a 1:2 scale device (37 m wide, weighing 320 tons) since 2008. Grid connected since 2012.
Flumill	2002	< 20	Tidal	Norway	2,1 MW 160 tonnes 18 x 48 meters	Development of a full-scale demonstration plant with two to four devices.
Langlee	2006	< 10	Wave	Norway	50 kW 70 tonnes 15 x 15 meters	Full-scale ocean testing is planned in the Canary Islands in 2015.
Minesto	2007	< 30	Tidal	Sweden	0,5 MW 7 tonnes 12 meters (wing)	A 1:4 scale pilot has been tested in the waters of Northern Ireland since 2012.
Pelamis	1998	< 50	Wave	UK	750 kW 1350 tonnes 180 meters	Has built and tested six full-scale units.

Seabased	2001	< 30	Wave	Sweden	100 kW 12 tonnes 4 meters (buoy)	Has manufactured the first 42 units (25 kW) of a 10 MW park, which is scheduled to begin operation in 2015.
Wello	2008	< 10	Wave	Finland	0,5 MW 220 tonnes 30 meters	Has since 2012 been testing a full-scale, grid-connected prototype in the Orkney Islands.

Our primary data sources are seven semi-structured interviews conducted in the case companies in 2012 and 2013 as part of a more comprehensive study of the emerging wave-and-tidal energy industry. The interviews lasted 60 to 90 minutes and focused on the basic product concept, the company background, investor involvement and financial challenges, the technology development process, the supply chain configuration and partnerships. All interviewees were senior managers or founders still active in the firms and were thus knowledgeable about their firm's history, development and status. All interviews were transcribed and manually coded.

Following the advice of Forbes and Kirsch (2011), we also collected an extensive amount of information from secondary sources, including the case companies' websites, news articles in local or national press, press releases, industry websites, industry reports, international industry-specific conferences (in the U.S., Canada, Scandinavia and the UK), publicly available consent applications and suppliers' websites. We combined the interview data with the data from the secondary sources to write 5- to 10-page case summaries of each company, which we sent to the interviewees for approval and fact checking.

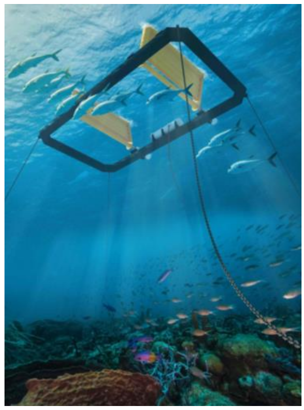
We follow the usual instruction on conducting multiple-case studies (Eisenhardt, 1989; Miles & Huberman, 1994) by first analysing and reporting each case separately before conducting a cross-case analysis related to supply chain configuration.

Case descriptions

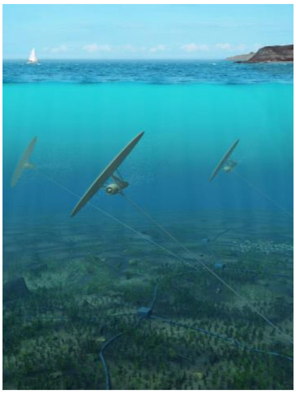
This section describes each of the seven case companies. The case descriptions briefly present the technological solutions before focusing on the firms' linkages to suppliers, their experiences in engaging suppliers and their organisation of device manufacturing. Figure 1 illustrates the main technology utilised in the seven cases.

FPP (P80)
www.floatingpowerplant.com

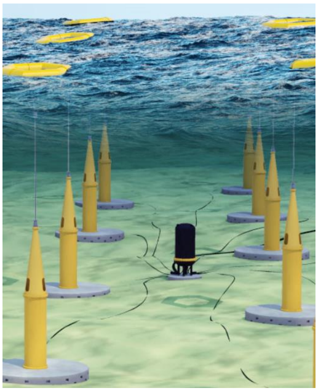
Flumill
www.flumill.com



Langlee
www.langleewavepower.com



Minesto
www.minesto.com



Seabased
www.seabased.com

Wello
www.wello.eu

Pelamis (bankrupt 2015)

Figure 1 – Examples of the wave-and-tidal energy harvesting technologies of the seven cases.

Case 1: Floating Power Plant (FPP)

Floating Power Plant (FPP) has developed a hybrid floating structure generating energy from both a standard offshore wind turbine and a unique hydraulic wave power take-off system, which it has developed in collaboration with a partner. FPP does not plan to manufacture anything in-house; instead, it has developed close relationships with suppliers of core technologies, and has organised these suppliers in a partnering network. According to FPP's CEO, this approach has both strengths and challenges: 'The way we approach innovation processes, there's a lot of benefits, you get a lot of resources, a lot of competence, a lot of experience, but our challenge is that we have to manage and motivate an organisation that is not ours'.

To engage suppliers in technology development, FPP has focused on understanding different suppliers' motivations for entering the industry (e.g. high profits due to future sales or an interest in learning about a new industry). For example, one of FPP's allied suppliers has been granted contracts related to the first sales if it can meet the market price. However, since its technology must be customised and tested over several years, FPP's ability to quickly switch to other suppliers is limited. Moreover, cooperating with *larger* suppliers has proved challenging for FPP. The rigidness of larger organisations often means that customising solutions to a small customer's needs is not a priority. On the positive side, FPP reports that large partners are extremely reliable and that, once they promise something, they do deliver on their promise. Being affiliated with large and established partners with solid engineering reputations also provides FPP with an increased legitimacy in the market. This legitimacy has opened doors to new partners and funders. In short, FPP's main strategy is to *ally* with both small and large suppliers for all manufacturing processes.

Case 2: Flumill

Flumill has developed the unique 'twin-corkscrew' tidal turbine. The main structure is mostly made of composite materials and will be mounted to the sea bottom in areas with a medium to high tidal stream. Because one of its owners is a firm that supplies composite structures to the offshore oil and gas industry, Flumill has been able to manufacture the main structures of the prototypes in its own production facilities. The largest of these was 48 meters long and 8 meters in diameter. The company plans to produce the future commercial units in-house. Suppliers are paid by the hour and develop the other components, such as the generator and electrical parts.

Because of the continuous emergence of new aspects and changes, Flumill cooperates with its suppliers in technology development. In the technology development stage, Flumill has found it easier to engage and work with small companies than with large ones. This is because Flumill has found smaller firms to be more agile and better able to move quickly, according to the changing requirements of the technology. Flumill has back-up suppliers for all different components, but the CEO emphasises that 'It's important for us to work together with our suppliers, so that we know what they are doing and can learn from them, but if we are not happy with them, we will replace them'. In short, Flumill prefers to build arms-length relationships with contracted suppliers that deliver to the company's own manufacturing facility.

Case 3: Langlee

Langlee has developed and designed a semi-submersible oscillating wave surge converter, which converts motion from two hinged flaps placed just under the water, into electricity. The company has focused on making its design as modular as possible so that it can easily sub-contract parts of the design and manufacturing. According to the CEO, 'At Langlee, we want to make our device as simple as possible, use standard components and prepare it for mass production'. The technology is split into three main components: the steel frame, the generator module and the power electronics. Langlee sought module suppliers that could supply entire kits for each component. The assembly of the final device is designed to be simple enough so that it can be done by most shipyards. Throughout the technology development process, the suppliers have worked on a contract basis in which each firm has been given specific tasks. These tasks are carefully documented to ensure that all of the development projects' intellectual property rights stay within Langlee.

The supply chain network configuration was chosen to prevent the company from becoming too dependent on any single partner. Langlee has switched out several suppliers during the development phase and states that all suppliers are easily replaceable. Still, the company suggests that having an interactive relationship with suppliers is a priority because of suppliers' valuable feedback on specific solutions, which benefits production and after-sales services. In short, through a strategy consisting primarily of modularisation, Langlee seeks arms-length relationships with replaceable commodity suppliers and contracted manufacturers.

Case 4: Minesto

Minesto is developing 'Deep Green', which is a kite-like structure anchored to the sea bottom with a tether. It moves across a tidal current in a circular or an eight-digit path to harvest energy. Minesto has divided the development of its tidal energy device into several subsystems and has established close partnerships with the suppliers that will manufacture the most crucial of these subsystems. Ideally, the company wants its suppliers to sell products similar to those of other companies, as this can decrease costs. However, some of the developed key components are so unique that Minesto cannot switch out its suppliers on a short- or medium-term basis. The suppliers are located all over Europe and consist of both small and global firms. Minesto has experienced that it is easier to initiate technology partnerships with smaller suppliers, as these are more willing to adapt to the company's wishes and are easier to cooperate with on a personal level.

Larger suppliers have proven more difficult to engage and more rigid to work with, as they prefer to provide off-the-shelf solutions and have been less willing to modify their products to suit Minesto's needs. On the other hand, Minesto believes that the larger suppliers are very trustworthy and are more likely to be able to handle production increases. Minesto has also experienced that a partnership with well-known suppliers open doors to new suppliers and funding sources, as illustrated by this quote from the CEO: 'We do not have the industrial test procedures that larger firms have. A partnership with them increases the confidence in our technology'. In short, Minesto maintains alliances with both small and large suppliers of core technologies. It also has a tight relationship with a contracted assembly manufacturer.

Case 5: Pelamis

Before Pelamis went bankrupt in 2015, its wave energy device was an attenuating line absorber. It was a huge floating tube divided into five sections and measuring 180 meters long and 4 meters wide. It generated power by the waves' movements, which force the device to rise and fall in snake-like motions. Pelamis was one of the first companies conducting successful tests of their wave technology in the early 2000s. This gave Pelamis a lot of publicity and it acquired a significant amount of private capital in an earlier phase of the industry. This funding made the company an industry leader, which again attracted more capital and made it possible for Pelamis to build its own production facilities in Edinburgh, Scotland, where the company produced six prototypes of its device. The device required special facilities for assembly and deployment, and after having built their first unit it was clear that internal manufacturing was a desirable solution. The senior manager explained as follows: 'Instead of contracting someone for the design and somebody else for the assembly, we realised that it is through in-house manufacturing we really learn about the product'.

Pelamis experienced challenges engaging the right suppliers. In the beginning, engaging large manufacturers was extremely difficult because Pelamis' device was so radical and the wave industry was almost non-existent. Furthermore, attracting larger suppliers to produce one-off components proved problematic. Instead, Pelamis engaged smaller suppliers, which are more flexible but are still not ideal, since they have limited financial and human resources. Pelamis' production of its first three prototypes led to extensive publicity, which (along with the fact that the product was now 'proven') attracted large suppliers that had dismissed Pelamis earlier. As a result, Pelamis switched out some of its smaller suppliers for larger ones. Although several of its suppliers offer modifications of their original components, Pelamis avoided exclusivity deals, instead focusing on having alternative suppliers for all of the components. In short, Pelamis preferred arms-length relationships with small and large suppliers that delivered to the company's own manufacturing facility.

Case 6: Seabased

Seabased has developed a wave energy technology that consists of a unit placed on the sea bed connected to a buoy on the surface via a line, which captures the energy in the motion of the waves and thus enables it to generate electricity. The company is a spin-off of the Swedish University of Uppsala. It has collaborated closely with the university on research and development ranging from theoretical concept studies to extensive, multi-year empirical testing in real ocean environments. This collaboration has given Seabased access to the university's personnel and facilities, allowing the company to develop core knowledge in both energy conversion and electrical transmission processes. The research at the university has helped finance the technology development and enabled Seabased to maintain a significant level of independence and protect its expertise.

Seabased has previously made 16 different prototypes, including both full-sized and smaller-scale prototypes. In 2014, the company opened a manufacturing facility in Sweden, where it has begun the manufacturing of devices for a pilot power plant consisting of around 400 devices. The strategically most important components used in the manufacturing process are commodities (e.g. magnets, cables and springs) which can easily be delivered by alternative suppliers. The company's long-term strategy is in-house mass production of devices, as exemplified by the following statement by the CEO: 'We feel that our set-up has a big advantage in series production'. In short, Seabased is a vertically integrated manufacturer with arms-length relationships with commodity suppliers.

Case 7: Wello

Wello's technology, the 'Penguin', converts the movements of waves to electricity. An asymmetric sea vessel is equipped with spinning rotators, which generate electricity as the vessel continuously adjusts to the waves. The full-scale device is 30 meters long and weighs 220 tons. Wello has focused on using existing, off-the-shelf components from the wind energy industry in the product design. This has given the company at least two to three choices for all of its device's components, allowing Wello to replace suppliers if necessary. The CEO explains as follows: 'We do not want to depend on any particular supplier, and always want to keep our options open'.

Wello does not plan to build anything in-house. The manufacturing of the main structure and the assembly of parts can be done by most shipyards. Despite Wello's focus on using off-the-shelf components, some supplier-developed components require minor modifications. Engaging potential suppliers has been hard since several suppliers have been reluctant to do one-off deliveries due to Wello's small size, especially when their components need to be modified to fit Wello's device. For its prototype, Wello chose a smaller shipyard to handle building and assembly. This smaller shipyard was interested in a long-term relationship and was thus willing to discuss and help solve Wello's problems, while larger shipyards were too difficult to cooperate with since building the prototype was such a relatively small order. In short, Wello's model is based on arms-length relationships with suppliers and contract manufacturers.

5 Cross-case analysis and discussion

Table 2 compares the case companies' component strategies, their decisions to make or buy their final devices and their ties to key suppliers.

Table 2 – Cross-case comparison of central supply chain configuration parameters.

Company	Component strategy	Make or buy final device?	Ties to key suppliers
Floating Power Plant (FPP)	Components developed in collaboration with suppliers/partners.	Buy	Strong ties. Long-term partnerships; key suppliers hard to replace.
Flumill	Manufactures composite structure itself, while other parts are delivered by suppliers.	Make	Weak ties. Collaborative development, but with the ability to easily replace suppliers.
Langlee	System is split into three modules, which different suppliers will deliver.	Buy	Weak ties. Collaborative development, but with the ability to easily replace suppliers.
Minesto	Components developed in collaboration with suppliers/partners.	Buy	Strong ties. Long-term partnerships; key suppliers hard to replace.
Pelamis	All components are delivered by suppliers and most are modified versions of off-the-shelf components.	Make	Weak ties. Collaborative development, but with the ability to easily replace suppliers.
Seabased	Core technologies and components are developed and manufactured internally.	Make	Weak ties. Most components are off-the-shelf or easy-to-replace commodities.
Wello	Suppliers deliver off-the-shelf components.	Buy	Weak ties. Most components are off-the-shelf and easy to replace.

Aligned with the models suggested by Geyskens et al. (2006), three generic supply chain configuration models can be derived from Table 2. Wello and Langlee have configured the most flexible supply chains. They typically source modules and contract assembly capacity through arms-length relationships. We call this model *the Market Model*. Minesto and FPP are the only two firms with strong relationships with key suppliers in which the development of core components occurs collaboratively. These firms have also developed strong ties with assembly contractors. We call their model *the Ally Model.* Finally, the last three companies, Flumill, Seabased and Pelamis, manufacture their final devices themselves and maintain weak relationships with materials suppliers. We call this model *the Maker Model*. Figure 2 illustrates the three models.

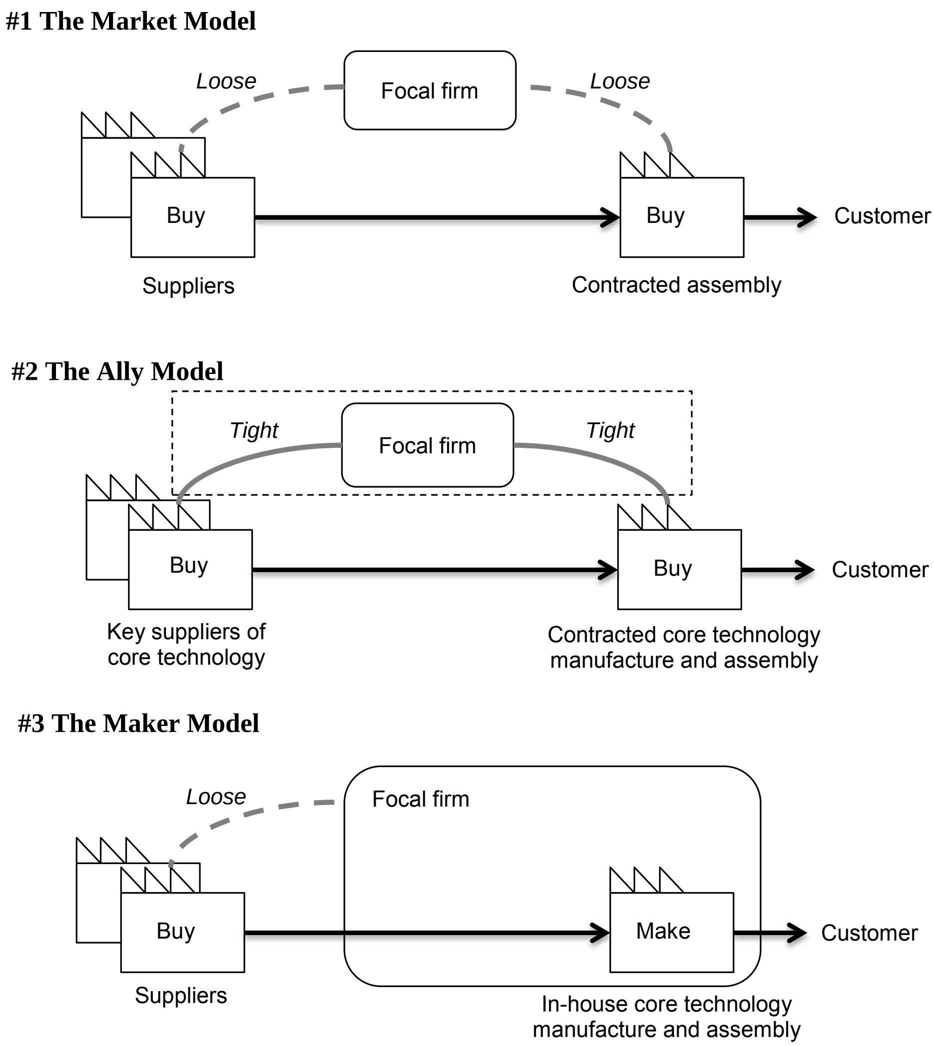


Figure 2 – Models of supply chain configurations in the wave-and-tidal energy industry.

The Market Model

The firms that utilise the Market Model outsource component production to suppliers and the manufacturing and assembly of the final device to contract manufacturers (e.g. yards). The firms do not regard any of their suppliers as key suppliers since they focus on using off-the-shelf components (i.e. components that already exist in the marketplace). They maintain weak ties to their suppliers because they want the flexibility to replace any supplier within a short timeframe, if necessary. Furthermore, because the focal firms do not consider any of the single components to be key technologies, their strategy is to deliver the design and integration of the total solution.

As long as components are commodities or need only minor modifications, the asset specificity is relatively low, and an arms-length buyer-supplier relationship is preferred. This gives the focal firms the advantage of being able to choose from among a wide variety of suppliers (Williamson, 1985), which helps to keep costs down and the time to market short. Another advantage of buying off-the-shelf components from the marketplace is that this approach also lowers technological uncertainty, which reduces transaction costs. The arms-length buyer-supplier relationship gives focal firms the flexibility to terminate non-functioning relationships and switch to other suppliers (Balakrishnan & Wernerfelt, 1986; Geyskens et al., 2006). Furthermore, the strategy of buying existing components makes it easier to identify and engage suppliers than if their components required major modifications. Finally, a generally high transaction uncertainty results in a preference for arms-length buyer-supplier relationships, which makes it possible to quickly reconfigure the supply chain (Geyskens et al., 2006).

However, the Market Model is not without challenges. Arms-length relationships with suppliers give the focal firms limited legitimacy. This is a clear disadvantage for small firms in emerging industries, which face extraordinary technological uncertainty. Being associated with credible suppliers is often very helpful in efforts to obtain funding and engage other partners (Aldrich & Fiol, 1994). Another disadvantage of an arms-length buyer-supplier relationship is the limited potential for learning from suppliers during the dynamic technology development process (Wu & Ragatz, 2010), which could help lower the time to market and the high technological uncertainty.

The Ally Model

Firms that use the Ally Model outsource the production of key components to closely managed suppliers. They also outsource the manufacturing and assembly of the final device to a local partner for power plant installation. Hence, they focus mainly on designing the device and conducting simulations, while collaborating closely with suppliers in joint research and development. These firms develop strong inter-organisational ties with key suppliers, which can help to ensure that they maintain control over core technology, despite outsourcing the production of core components (Lambert & Cooper, 2000).

Both the final devices and the components developed with the suppliers are highly asset-specific. According to Williamson (1975), this should imply a decision to ‘make’; however, as this is not a realistic option for these companies because of the high financial requirements, the preferred solution is a close relationship with key suppliers, which can reduce transaction costs (Dyer, 2002). Furthermore, a close relationship with suppliers can enable those suppliers to commit to investing in the development and future manufacture of components, which can significantly reduce the transaction costs (Dyer, 2002) and capital requirements of the technology development process. This close relationship also limits the transaction uncertainties (and associated costs) between the supplier and the focal firm. Additionally, having strong ties with renowned suppliers gives a focal firm credibility with external stakeholders, such as policy-makers, investors and partners. This can be crucial for growing the market for small firms in emerging industries (Aldrich & Fiol, 1994; Zimmerman & Zeitz, 2002).

One of the drawbacks of the Ally Model is that development of strong ties with suppliers in the technology development process creates a lock-in effect. As a result, components can become *too asset-specific*, leading to higher production and transaction costs and making the final product less attractive or even obsolete (Williamson, 1985). This is especially the case for firms in emerging industries, which are often engaged in a dynamic technology battle with few industry standards. Moreover, numerous strong ties may be difficult to manage over time, especially for small firms with limited human resources. Hence, a central challenge for small firms in this model is to maintain good and fruitful relationships with key suppliers while simultaneously avoiding being locked into any exclusivity deals.

The Maker Model

The firms that use the Maker Model manufacture and assemble their devices in their own manufacturing facilities. They have arms-length relationships with their suppliers, which deliver commodities or components with only minor modifications. Key components are kept under internal control and are manufactured by the focal firms in-house.

When final devices are characterised by high asset specificity, transaction cost economics advises to organise the manufacturing hierarchically to minimise transaction costs. Furthermore, the high transaction uncertainty in emerging industries favours a hierarchical organisation, which gives focal firms greater control over internal relations (Williamson, 1975). Another clear advantage of a hierarchical organisation is that it gives firms full control over the development and manufacturing of core technology. Furthermore, as suppliers in this model only deliver commodities or components with minor modifications, focal firms can maintain arms-length buyer-supplier relationships. This configuration gives them a wide choice of suppliers in the short to medium term, thereby helping to reduce transaction costs (Williamson, 1985).

On the other hand, a clear disadvantage of this model is the significant financial investment needed to build manufacturing facilities and expand the organisation. In addition, the size, weight and complexity of the products require expensive and specialised production assets. This could represent a major obstacle for small firms, especially within capital-intensive industries like the wave-and-tidal energy industry in which funding is hard to obtain (Leete et al., 2013). As our case descriptions illustrate, the case companies have followed different paths that led to choosing the Maker Model. The position as a frontrunner in the industry helped Pelamis attract a considerable amount of private capital. Seabased's tight connection with the university directly benefited its technology development (and lowered its financing requirements), while Flumill accessed production facilities through one of its owners. This made it possible for these three firms to overcome the financial challenge and invest in developing their own technology and assembly or manufacturing facility. As in the Market Model, maintaining arms-length relationships with suppliers gives the focal firms utilising the Maker Model limited legitimacy via suppliers.

Implications for theory and practitioners

The findings offer several implications for theory and practitioners. We find that while transaction cost economics is useful in discussing make-or-buy discussions in the emerging wave-and-tidal energy industry, it also has its limitations. A problem with applying transaction cost theory in an emerging industry is the fact that it is not necessarily only the focal firms' decision to buy, make or ally. As our findings show, acquiring financing to build technology internally, engaging suppliers willing to make small-scale deliveries and modifying existing or developing new components could all be very difficult in the early stages of an emerging industry where uncertainty is high. Moreover, the central aspects of our analysis, such as a focal firm's legitimacy, are not directly incorporated in transaction cost economics. Collaboration with a respected supplier is likely to increase a firm's legitimacy among other actors and makes it easier to attract new suppliers willing to collaborate.

Our findings also suggest that when an industry is in the early stages—before any technology has become dominant—there is generally higher asset specificity among technologies than in mature industries. The high asset specificity limits the number of suppliers and contractors, which increases the likelihood that some of the focal firms cannot choose the buy option since there are few relevant components available to buy and integrate.

For practitioners, the three models in Figure 2 can be useful in strategic discussions of what type of supply chain configuration a firm in an emerging industry should aim to build in the first place. Instead of engaging in an unstructured search for suppliers and development partners, new ventures in emerging industries could use the proposed models to make more informed make, buy or ally decisions.

The specific cases also offer advice regarding which types of suppliers to engage, which is a choice that all case firms noted to be particularly difficult in emerging industries. In particular, finding allies that are willing to take part in the technology development process is a challenge. A key question for many firms is which type of supplier to engage: That is, are large, established suppliers (e.g. Siemens, ABB etc.) better than small, specialised suppliers? Our case companies found engaging large suppliers to be more difficult than engaging small suppliers. Small suppliers are often more flexible with regard to customisation and product modification than larger suppliers. On the other hand, larger suppliers are generally not interested in small-scale production and are hard to convince regarding the potential of 'unproven' technologies in an emerging industry. Several of the firm's representatives reported struggling with bureaucratic decision-making and a heavy focus on intellectual property rights when collaborating with large suppliers. Smaller suppliers are more flexible and less formal, resulting in a better fit with the focal firms' characteristics. However, larger suppliers are usually very trustworthy in terms of delivering what is promised, which reduces behavioural and technological uncertainty. They can also scale up production if necessary, resulting in lower production costs. Finally, large suppliers have the advantage of a legitimacy effect, which is critically important in emerging industries. Some of the cases in this paper have used a stepwise approach where they initially have collaborated with a small supplier, but later (once their technology was more developed and 'proven') switched to a larger supplier.

Conclusion

This paper has focused on an understudied area in both the supply chain literature and the literature on emerging industries: the configuration of supply chains in emerging industries. Overall, the study confirms that it is very challenging to strategically configure supply chains in the early stages of emerging industries. In these industries, there are often no established supply chains in the first place. Therefore, firms often engage in unstructured searches for suppliers and partners. Our purpose was to explore how these firms can configure more suitable supply chains. Through a multiple-case study of seven companies in the wave-and-tidal energy industry, we identified three general models of supply chain configurations in emerging industries. We focused on the decision to either make or buy components and manufacturing capacity, as well as on firms' levels of integration with suppliers.

The three proposed supply chain models for emerging industries are as follows: (1) the Market Model, (2) the Ally Model and (3) the Maker Model. In short, the decision to manufacture or assemble the final device (i.e. the Maker Model) gives the focal firm control over key competences or technologies. However, though classical arguments in transaction cost theory prefer this model, it is particularly difficult to realise in emerging industries due to resource requirements. A particular challenge is the need to attract the necessary investment capital. Hence, the more realistic models are the Ally Model and the Market Model. The Ally Model prescribes a close relationship with suppliers, which offers the advantages of access to the suppliers' technological competences and a potential credibility effect in dealing with external partners and funders. Whereas alliances with small and flexible suppliers is often the best option in early-stage development, alliances with larger, more established suppliers is preferable when a firm wants to scale its business for the market. Finally, the Market Model, based on arms-length relationships with suppliers, keeps alternatives open but lacks the benefits of cooperative technology development and legitimacy-building partnerships.

Limitations and future research

A particular challenge when researching emerging industries is the limited availability of cases. Firm turnover is generally very high, and the highly dynamic environments of emerging industries can quickly change the research setting. In this study, we include only seven cases from five Northern European countries. It would be interesting to see whether our findings are valid for companies in other geographical contexts and emerging industries. A second limitation of our study is that only one of our case companies has already begun commercial production. Hence, our data are based on the firms' development thus far and their plans for the future, and does not capture if their decisions to make-or-buy will further evolve before commercialisation. It is necessary to conduct more longitudinal studies to investigate how firms' make, buy or ally decisions develop over the course of the commercialisation phase. Third, this study has focused on the development of supply chains for small firms in the emerging wave-and-tidal energy industry; thus, we recommend caution in generalising to other emerging industries. However, we do believe that our findings could be transferable to other capital-intensive industries with characteristics similar to those of the wave-and-tidal energy industry, such as, for example, other renewable energy industries. Finally, whereas other theories could add to our understanding, we investigated supply chain configuration in emerging industries using the transaction cost economics exclusively. These limitations provide good opportunities for future research.

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Article 4:

The entry of MNCs into an emerging industry: the choice of entry mode and the role of uncertainty

ARTICLE 4

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