Should tidal energy projects be run by the public sector? An examination of Natural Resources Wales

Contents

1.0 Introduction

1.1 Introduction to tidal energy

Tidal energy is a form of hydropower which harnesses the power that is generated from the tides of the ocean. The energy is converted into forms of power, primarily electricity (Shetty and Priyam, 2022). Tidal energy is a fairly new renewable energy concept, that has been praised for being highly predictable and consistent as it stems from gravitational forces derived from the moon and sun on the earth's oceans. This gives tidal energy an advantage over the likes of solar and wind energy which are weather-reliant to harness power (Astariz, et al 2015). Therefore, tidal energy offers a consistent, clean energy alternative, by not emitting harmful greenhouse gas emissions, which is becoming ever crucial in the global fight against climate change (Khare and Bhuiyan 2022). As a result of these advantages, tidal energy has become an increasingly popular form of renewable energy in regions that have access to significant tidal ranges and strong tidal currents (Boretti, 2022). Examples such as the La Rance Tidal Power Station in France which takes advantage of the substantial tidal range of the Rance River estuary, or the Annapolis Royal Generating Station in Canada, built on the Bay of Fundy which has the largest tidal range in the world (Boretti, 2022). The Annapolis Royal Generating Station was shut down in 2019 due to the substantial fish mortality caused by the turbine (Withers, 2021). One of the major issues regarding tidal energy is the potential damage it can cause to nearby wildlife, through habitat destruction, noise pollution and collision with turbine blades (Polagye et al, 2011). In extreme cases such as the Annapolis Royal Generating Station, this can lead to the shutdown of the project entirely (Withers, 2021). Other factors such as the high cost of developing and operating tidal energy projects and the reliance on a relatively new technology pose challenges for the implementation of tidal energy (Astariz, et al 2015).

1.2 Tidal Energy in Wales

Tidal energy is an ever-growing renewable energy opportunity in Wales to achieve its target of net zero carbon emissions by 2050, (Welsh Government, 2022). Wales boasts some of the highest tidal ranges in the world, particularly in the Severn Estuary at 15m and Swansea Bay at 10.4m. This can offer a reliable and predictable source of energy (Roche et al, 2016). An initial plan was to develop a tidal lagoon located in Swansea Bay, however, plans for a publicly run tidal lagoon project were scrapped due to financial limitations in 2018 (Vaughan, 2019). This has led to plans in 2023 for a new project named “Blue Eden”, that would be completely funded by the private sector, resulting in minimal intervention from the Welsh and UK governments (Youle, 2023).

This debate leads to the purpose of this study, of whether tidal energy projects like the Swansea Bay tidal lagoon should be run by the public or private sector.
Tidal energy projects have been successfully run by both the public and private sectors in the past. Private ownership has often been associated with efficiency and innovation, which is mainly driven by market competition (Igoe, 2007). An example of this is the Shetland Tidal Array run by private energy company Nova Innovations, which has spearheaded tidal energy technology through the project's high energy capacity (Santos-Herran et al, 2019). Public ownership can be beneficial in aligning renewable energy projects with environmental and social goals. An example is the Three Gorges Dam in China, the world's largest power station, which needed to be substantially large to meet the demands of China's large population and energy demand (Gleick, 2009). Attitudes amongst the public can change based on whether a project is carried out by the public or private sector (Kallis et al 2010). In California, a survey showed that negative attitudes were apparent towards privately run water companies, with many members of the public stating they would rather pay a higher price for water services if it was run by the public sector (Kallis et al, 2010). However, in Bangladesh Non-governmental organisations tend to gain greater public participation in environmental impact assessments, when compared to governmental organisations. This can show there can be apathy towards public bodies when the government is particularly unpopular such as in the case of Bangladesh (Hasan et al, 2018). Whereas, in California polling showed a 60% voting majority in 2008 and 2012 for then-President Barack Obama (Bowen, 2008; Bowen 2012), showing the US government's popularity in California, which allows more positive attitudes towards the public sector (Hasan et al 2018).

Tidal energy has an under-utilised potential in Wales, despite plans being made for smaller tidal stream energy projects in Anglesey and Pembrokeshire (Morlais, 2019; Marine Energy Wales, 2023). Therefore, this study can provide the most effective way of developing tidal energy projects in Wales, whether they should be run by the public or private sector. The study will also examine whether NRW is fit for this purpose, in an environmental monitoring role or developing a tidal energy project. Whilst existing research has already explored the effectiveness and environmental impacts of tidal energy such as (Shetty and Priyam, 2022), there are gaps in the case of tidal energy's potential in Wales. The benefits and drawbacks of public sector management in water conservation have been explored by (Kallis et al 2010), however, this study focused on California as an example. Therefore, this study will aim to contribute to the discouragement of renewable energy governance, by focusing on how tidal energy can be most effectively run in Wales.

1.3 How the research will be conducted

This example sets the base for the research in determining whether publicly or privately run tidal energy projects are more effective. By examining Natural Resources Wales's (NRW) role in overseeing tidal energy projects and how effective they are in doing so will be integral in determining the effectiveness of a publicly run organisation in its environmental management. To find this out online surveys will be sent out to willing participants who have a sufficient knowledge of tidal energy. The participants will come from different backgrounds, gaining a variety of insights from the public sector, private sector and academia. The surveys can help gain insights into how the private sector and public sector have different motivations and driving factors when developing a tidal energy project. It will be important to look at previous tidal energy projects from overseas and consider how successful they have been, by looking at examples of projects from both the public and private sectors. By evaluating the successes and failures of previous projects can provide a better understanding of how to make tidal energy work most effectively if implemented further in Wales. It can be difficult to judge the success of a tidal energy project, however the factors that will be used to determine how successful previous tidal energy project will include; its reliability, the economic benefits, social acceptance and benefits to the community, its innovation and its long-term sustainability (Howell and Drake, 2012). The main factor to determine a successful project will be its environmental impacts, because a tidal energy project in Wales must cater towards legislation such as the Environment (Wales) Act 2016. This emphasises the need to maintain and enhance biodiversity and ensure natural resources are used sustainably (Welsh Government, 2016). The Wellbeing of Future Generations (Wales) Act 2015 further requires tidal energy projects to limit its damage to the environment by ensuring the long-term impacts of a tidal energy projects are considered in its development, such as limiting damage to ecosystems and biodiversity (Welsh Government 2015). By ensuring that tidal energy projects are environmentally sustainable can help them succeed in the long-term. It can be more cost effective to initially design a tidal energy project with environmental protection in mind, rather than mitigating the damage once it has already occurred (Denny, 2009). Protecting the environment can help gain the support of local communities, that rely on marine environments for tourism, recreation and commercial fishing (Devine-Wright, 2011). Therefore, considering the environmental impacts can encompass other factors like economic benefits and social acceptance, making the tidal project more successful and sustainable in the long-term (Neill et al, 2021).

1.4 Aims and Objectives

The primary aim of the research is to critically examine the role of the public sector, in this case NRW in the development and management of tidal energy projects in Wales. The surveys will aim to find out:

- Explore the benefits and challenges of public sector involvement in tidal energy development compared to the private sector
- Examine the driving factors behind public and private sector involvement in tidal energy projects
- Examine the potential role of Natural Resources Wales for future tidal energy projects in Wales

The survey responses will aim to gain a better understanding of these secondary objectives in order to answer the main question: Should tidal energy projects be run by the public sector? Online surveys be used to allow the researcher to gain further insights on topics that may not have initially been intended.
Hypothesis: Tidal energy projects that are managed by the public sector can offer greater societal benefits and environmental sustainability when compared to the private sector. However, acknowledging that the public sector faces significant challenges and limitations through financial constraints and political barriers. This is supported by the participants who have a favourable view on previous environmental projects yet agree there are ways NRW can improve to become more environmentally sustainable. This argument is further supported by previous literature suggesting that although there are several valid criticisms of NRW, in theory the public sector has a better understanding of the needs and wants of the communities the projects are operating in.

2.0 Literature review

2.1 Introduction

Tidal energy is still in its infancy as a renewable energy source, yet it remains a promising source of sustainable power, due to its potential to supply a consistent reliable source of energy by using the natural flow of the tides (Todeschini, 2017). Whereas other more common forms of renewable energy such as wind and solar are weather-reliant to provide energy (Astariz, et al 2015). The question of how renewable energy projects can be most effectively managed still remains. Several research studies have been conducted on the benefits and drawbacks of several renewable energy projects, such as the Three Gorges Dam in China (Li et al, 2013) and the Belo Monte Dam in Brazil (Fearnside, 2017). One of the main drawbacks regarding tidal energy is its high costs, due to the technology for tidal energy also being in its infancy. Therefore, this can leave issues that the public sector may be unable to fund a large tidal project such as in the case of the Swansea Bay tidal lagoon proposal (Waters and Aggidis, 2016). This shows the complexity of the public vs private sector debate, as one of the main factors why a renewable energy project may be run by the private sector can come down to having more available capital, rather than its proposal for the project being innovative or more efficient (Polzin et al, 2019).

Wales was selected as an example for this study based on how tidal energy projects should be run, due to its geographical advantages of possessing high tidal ranges and strategic coastal locations (Angeloudis et al, 2015). In Wales, plans have been made to push the development of renewable energy in order to meet targets of achieving net zero carbon emissions by 2050 (Welsh Government, 2022). Legislation such as the Environment Act 2016 and the Wellbeing of Future Generations Act 2015 (Welsh Government 2015; Welsh Government 2016) set targets for addressing climate-related issues, such as by increasing the usage of renewable energy. An initial plan was to develop a tidal lagoon located in Swansea Bay. However, plans for a publicly run tidal lagoon project were scrapped due to financial reasons in 2018 (Vaughan, 2019). This led to plans in 2023 for a new project called “Blue Eden” that would be completely funded by the private sector, leaving room for minimal government intervention (Youle, 2023). This leads to the purpose of this study and whether tidal energy projects like the Swansea Bay tidal lagoon should be run by the public or private sector. This study will additionally analyse whether NRW is suitable to oversee the development and operation of a tidal energy project. Given the recent controversies of NRW recording 105,943 sewage spills into Welsh rivers and lakes, one of which is into a protected dolphin habitat in Cardigan, gaining mass media attention (Horton, 2023; Duffy, 2024). Therefore, this left concerns amongst the public that NRW are unable to effectively fulfil its role.

2.2 How effective is the public sector?

There are several examples of large innovative infrastructure projects have been run successfully by the public sector. An example is the Three Gorges Dam in the Yangtze River in China, which is the world's largest power station. The dam has been praised for providing clean energy without greenhouse gas emissions and reducing flood risk for nearby communities. Despite this environmental, economic and social concerns have been raised about the project regarding corruption and damage to ecology (Li et al, 2013). The Yangtze River Basin is home to 36% of all freshwater fish species in China (Xie, 2003). The project causes concern that these species along with the heavily endangered Chinese freshwater dolphin could be lost (Hance, 2008).
The La Rance Tidal Barrage is the world's oldest tidal power station and is run by 'Electricite de France' a state-owned electricity company. The project has been praised for its longevity and reliability, proving to be relatively cost-effective despite its initial high construction costs (Frau, 1993). The La Rance project has been criticised for causing the displacement of plaice and sand-eels from the Rance River. The construction of the barrage has altered the sediment and natural hydrology of the estuary, leading to changes in water quality (Kirby and Retière, 2009).

2.21 Centralised public sector renewable energy projects

The La Rance project and the Three Gorges Dam project are both run as a centralised, national project. These projects have been criticised for their negative environmental impacts, that occurred during the project's construction. This can show that large centralised tidal energy projects can be ineffective by having a lack of understanding of local ecology in where the project is being built (Gleick, 2009). However, large, centralised projects are likely to go through more rigorous checks and balances, governed by national environmental policy due the scale of the project. Centralised projects are likely to undergo review through extensive environmental impact assessments and monitoring measures to mitigate damage to the environment (Mann and Gennaio, 2010).

2.22 Issues with public sector renewable energy projects

Political agendas can be a significant factor in tidal energy projects that are run by the public sector. Political priorities may lie in economic development, which can result in the relaxation of environmental regulations and monitoring (Feiock and Stream, 2001). This has been the case in the Three Gorges Dam project in China, where decisions are

made from a centralised authority, leaving little input from local stakeholders in large projects (Huang et al 2010). The priority for the Chinese government in the Three Gorges Dam project was the production of renewable energy and to reduce the national reliance on coal. Therefore, the damage to freshwater dolphin and fish habitat are overshadowed by the priority for economic and infrastructure growth, especially in such as large country like China (Wu et al 2013). Governments and public bodies may change their attitudes towards renewable energy projects depending on public support for political gain, which can be prominent during election years. This can make it difficult for renewable energy projects to be built if a government is trying to appease the public. The 'Not in My Backyard Syndrome' can lead to local opposition from people opposing renewable energy projects over concerns about aesthetics, conflicts regarding the use of agriculture (Van der Horst, 2007). This has been an issue in Wales as there has been local opposition to the Pen y Cymoedd wind farm and the Morlais tidal energy project in Anglesey (Parkhill and Cowell, 2016; Kudelska, 2019). This can lead to delays in the project's development, by a change in political priorities, community resistance and more extensive environmental reviews (San Martin, 2023). Therefore, this can emphasise the need for proactive community engagement in tidal energy projects in Wales to prevent public opposition from delaying a projects development.

2.23 Decentralised public sector projects

In Norway, environmental conservation powers are often transferred to local governments which can facilitate a greater degree of local knowledge of environmental projects (Falleth and Hovik, 2009). By taking the opinions of local people into account, local authorities put greater importance on achieving local goals and values even when it counters national government policy or international obligations. Local authorities are responsible for representing the interests of their community and can engage with stakeholders in the decision-making process to ensure local ecological concerns are taken into account during the project development process (Falleth and Hovik, 2009). Local authorities and stakeholders are often more familiar with local environmental conditions and can implement conservation measures that are better suited to local priorities (Naylor et al, 2019). However, there can be a certain degree of bias in a decentralised environmental management system, by prioritising local interests that may be considered insignificant, compared to the broader environmental conservation goals that may be more important to consider (Wu et al, 2020).

2.24 Decentralised public sector projects in Wales

Decentralised environmental projects have been successful in Wales, such as the Gower Landscape Partnership. This project aimed to protect and enhance the habitats within Gower and preserve the Gower's cultural heritage. The project was run as a

collaboration, receiving funding from NRW and Swansea Council whilst the project was mainly driven and implemented by non-profit organisations and volunteers (Swansea Council, 2017). The Gower landscape project represents a holistic approach to environmental conservation by bringing together different stakeholders and sectors for a common goal (Berkes, 2010). A decentralised approach to tidal energy projects can help mitigate damage caused to nearby ecology by collaborating with local non-profit organisations and levering their understanding of local ecology (Falleth and Hovik, 2009). Damage to the environment is one of the main issues in tidal energy (Polagye et al, 2011) projects such as in the case of the Three Gorges Dam and the La Rance tidal barrage, however these were significantly larger projects compared to the Gower landscape project. It can be difficult for local communities to gain any sort of decision-making power when on a national scale project (Hovik and Hongslo, 2017).
It can be difficult to compare environmental projects in Wales or Norway, to similar projects in China or France due to the significant cultural, political and economic differences between these countries. For example, in China decision regarding renewable energy projects like the Three Gorges Dam are made by the centralised, authoritarian, Chinese government (Wu et al 2020). Whereas Norway is a democratic country, that will put a greater emphasis on local stakeholders in its decision-making under a decentralised governmental system (Falleth and Hovik, 2009). Despite these differences, it is still important to compare different publicly run environmental projects from around the world, to gain a better understanding of how tidal energy projects can be most effectively run in Wales.

2.3 How effective is the private sector at running renewable energy projects?

2.31 Motivations of the private sector

The private sector will likely have different motivations than the public sector when constructing tidal energy projects. Although private sector organisations can differ between for-profit companies, non-profit organisations, co-operatives and social enterprises, all of which are likely to have different goals and motivations in renewable energy development (Jurkiewicz et al, 1998). Although, for-profit companies are the most common private sector organisation in developing renewable energy projects (Goedkoop and Devine-Wright, 2016). A major issue regarding the private sector running environmental infrastructure projects is the profit motive can often outweigh the incentive for effectively managing the local environment (Biermann, 2022). The profit motive can lead to corners being cut on environmental assessments, which can lead to ecological damage, neglect of community engagement and evasion of regulation and policy (Hinton, 2020). Private companies can be encouraged to follow the profit motive and neglect the conservation of an area as a result of overly relaxed policies. Capitalism

and the profit motive have been major reasons in history for environmental degradation such as the Industrial Revolution leaving poor air quality in major cities (Beatley,1989). Beatley uses the example of Reagan's 1981 executive order 12291 in which environmental regulations must undergo a cost-benefit assessment and the benefits must outweigh the costs. Therefore, showing that profit is the main priority for privately run tidal energy projects (Beatley, 1989). Whereas the main priority of renewable energy should be environmental sustainability by reducing carbon emissions and preserving natural ecosystems, rather than its economic benefits (Assadi et al, 2022).

2.32 Issues surrounding private sector involvement in renewable energy projects

There are concerns surrounding the private sector that there may be cost cutting measures in tidal energy projects to maximise profits, leading to a tidal project that is of a far lower quality if funding has not gone back into the project itself, maximising its efficiency and quality (Clark, 1973). This can be a significant issue for tidal energy specifically, where there is a high risk of causing environmental degradation and harm to wildlife. It can be concerning if a private company was to cut corners in its environmental assessments, causing unanticipated harm to marine life and habitats (Segura et al 2017). In other circumstances, deregulation and privatisation have been heralded as the key to conservation success (Igoe, 2007). Economic incentives can allow private companies to be rewarded for acting sustainably, such as by government subsidies for implementing wildlife protection measures, giving private companies motivation to build an environmentally sustainable project (Rode et al, 2015). This can be an important factor in Wales, as economic government grants can encourage the development of tidal energy projects in specific regions, which can boost local economies (Smart, 2007). This can be beneficial in Wales, as Swansea can benefit from the construction of the proposed tidal lagoon through job creation, supply chain benefits and tourism. This is important for a relatively deprived region like Swansea where 11.5% of Swansea's 148 LSOAs are in the most deprived 10 per cent in Wales (Swansea Council, 2019).

2.33 Examples of renewable energy projects run by the private sector

The Belo Monte hydroelectric dam in the Amazon Rainforest run by a private consortium and developed by a private energy company Norte Energia. The project received criticism for displacing indigenous tribes such as the Juruna and Xirkrin people and the extinction of several plant and animal species (Fearnside, 2017). Despite the Dam project being ran by a private consortium it received tacit support from then Brazilian President Jair Bolsonaro whose neoliberal policies prioritised capital gain over the preservation of the Amazon (Deutsch, 2021). Proposed amendments to the 'Forest

Code' relaxed restrictions on land use and deforestation allowing for harmful development in the Amazon (Deutsch, 2021). However, the private energy company Nova Innovation have been praised for its leading tidal energy technology in the Shetland Tidal Array in Scotland. Unlike many tidal power projects Nova Innovations have been applauded by environmental groups such as the WWF for its limited harm to local wildlife (Carrell, 2016). The Shetland Tidal Array project uses innovative technology in its energy converters that are far less harmful to the marine environment, compared to other tidal technologies (Santos-Herran et al, 2019). Therefore, the success of a privately run tidal energy project can depend on factors such as technology, funding and planning when considering their impact on the environment.

2.34 Community involvement within the private sector

It is noted that community involvement in a tidal energy project is an important way of gaining local knowledge and building trust, leading to a more successful and sustainable outcome (Berkes, 2010). Community involvement is usually attributed to the public sector by involving local councils, such as in the case of the Gower Landscape project in South Wales (Swansea Council, 2017). However, this strategy can be undertaken by the private sector, as the Shetland Tidal Array project installed a 'community-owned' turbine that was primarily funded by the Shetland Island community (Anstiss, 2024). Involving the community in this way can enhance public relations and trust for the project, which is especially important in the private sector where there may be concerns from the public that the tidal project is solely motivated by profit. The 'community-owned' turbine can emphasise the benefits that the tidal energy project will have on the local community, by showing the benefits of green energy and economic opportunity for the Shetland Islands (Mirzania et al, 2019). Privately run tidal energy projects can have 'trickle-down' effects, where the benefits of the projects can be shared amongst shareholders and local communities (Knuth, 2018). Such as in the case of the Shetland Tidal Array and governments reaching renewable energy targets to reach net zero.

2.35 Tidal energy policy and regulations

It needs to be noted that strict regulations and guidelines such as environmental impact assessments are required for large environmental projects, such as a tidal energy project, which apply to both the public and private sectors. Such legislation deters private companies that are attempting to cut corners for the sake of profit from damaging the local environment to a certain extent (Kraft, 2021). This can lessen concerns that the private sector is more likely to damage nearby ecology if effective environmental policy is followed carefully. It is highly unlikely that a private company would show signs of apathy towards environmental regulations while this deterrent is in

place. Policy such as the 1981 Wildlife and Countryside Act in the UK, prevents intentional harm to water mammals in the UK's waters (UK Government, 1982). Therefore, if a tidal energy project was found to be significantly harming surrounding wildlife it could lead to the shutdown of the project entirely (Horne et al 2021). A private company would not only be required to follow government policy by law but also due to the risk of damaging the company's reputation (Vandenbergh, 2013). An example of this is the Canadian energy company Sustainable Marine's reluctance to develop a tidal energy project in The Bay of Fundy in Nova Scotia, because of the potential backlash from local environmental groups. This was due to the potential impacts on culturally and ecologically significant species such as White Sharks, American eel and tomcod (Austen, 2022; Donovan, 2022). Therefore, there are motivations to make a successful tidal energy project in both the public and private sectors, although for different reasons (Vandenbergh, 2013).

There are many examples of successful tidal energy projects that have been run by both the public and private sectors. An example is the publicly run La Rance tidal energy project in France, which can be praised for its longevity (Frau, 1993), and the privately run Shetland Tidal Array in Scotland, which is supported by wildlife groups and praised for its technological innovations (Carrell, 2016; Santos-Herran et al, 2019). This can show that it may come down to factors such as a lack of environmental awareness, or not looking at the long-term sustainability of a tidal project that deems how successful a tidal energy project is.

2.4 The Role of Natural Resources Wales

The role of NRW as stated in the Environment (Wales) Act 2016 is to "pursue sustainable management of natural resources" (Natural Resources Wales, 2016). NRW are also responsible for environmental regulation and enforcement, in areas such as waste management and conserving biodiversity by mitigating environmental harm.

NRW must act as a regulatory body for environmental projects like tidal energy projects. Its regulatory framework aims to ensure there is compliance with environmental policy, mitigate potential risks and safeguard the interests of communities in Wales (Jenkins, 2018). The environmental impact assessment for the Morlais tidal stream energy project in Anglesey was written and produced by NRW (Morlais, 2019). The project and NRW came under criticism for their lack of consideration for water mammals in the vicinity of the demonstration zone, as the environmental impact assessment claimed seals and dolphins have the potential to 'collide' with the tidal energy turbines (Morlais, 2019; Coles et al, 2021). Therefore, NRW failed to act as an effective regulatory body, by

potentially breaking the 1981 Wildlife and Countryside Act, by failing to mitigate intentional harm to seals and dolphins off the coast of Anglesey (UK Government, 1982; Kelly, 2022).

2.41 Natural Resources Wales's formation

NRW was formed in April 2013 after a merger of three public bodies in Wales consisting of: The Countryside Council for Wales (CCW), the Environment Agency Wales (EAW), and the Forestry Commission Wales (FCW), (Lewis 2015). Reasons for the restructuring of public environmental bodies in Wales centred around a reduction in costs, the Welsh Government claimed the new body could produce savings of £158 million over ten years (BBC, 2011). The rationale for the merger has led to criticism of being far too financially focused, as opposed to effective management of natural resources, which should be a priority (Lewis, 2015). Lewis, 2015 argues that the statutory duties imposed on NRW, that are related to nature conservation are far weaker than that of the former CCW which has led to conflict between the previous bodies (Lewis, 2015). Other views state that NRW was formed as a result of failure to meet the 2010 EU biodiversity targets, leading to a new more efficient approach to natural resource management in Wales (Warren, 2013). Therefore, the formation of NRW was not purely a result of cost-saving measures from the Welsh Government but formed as a new strategy to meet ambitious targets relating to sustainable development (Warren, 2013).

Criticisms were made that the initial board of NRW did not include any representatives from the FCW (Lewis, 2015). Despite losing representation in the initial board of NRW, the Forestry sector of NRW has since been praised for its social innovation in running community-led woodland projects (Ludvig et al 2018). An example of this is the current 'Woodlands and You' projects, based in Conwy, Powys and Carmarthenshire. The project aims to encourage the community use of the national forestry estate and the protection of natural biodiversity (Ludvig et al, 2018). Despite moving to a centralised management system, NRW has worked effectively with communities across Wales in forestry-based conservation.

2.42 Natural Resources Wales's shortcomings

NRW has come under scrutiny for failing to carry out its role of pursuing sustainable management of natural resources effectively. The failure to manage sewage is one of the main examples of this, as in 2023 105,943 sewage spills were recorded into Welsh rivers and lakes in 2023 (Duffy, 2024). This included a sewage spill into a protected

dolphin habitat in Cardigan Bay in 2023, which gained mass media attention (Horton, 2023). This scrutiny has led to questioning from the Senedd of whether Natural Resources Wales is “equipped to do its job” (Scurlock, 2023).

2.43 Natural Resources Wales’s funding

NRW’s sewage mismanagement can be attributed to a lack of funding (Bateman and Balmford, 2018). Funding gaps have been found in NRW, as core funding remained unchanged in 2023/24 (Scurlock, 2023). Insufficient funding can lead to staff shortages, limit ability to monitor environmental infrastructure projects and hinder the ability to invest in new technology, leading to unsatisfactory public service delivery (Bateman and Balmford, 2018). Therefore, funding can be a significant factor in affecting how capable NRW are at carrying out their aims and responsibilities. This lack of funding can lead to NRW being unable to develop and monitor tidal energy projects in Wales, leaving them to be outsourced to the private sector. The majority of renewable energy projects in Wales have been outsourced to private companies, potentially due to NRW’s lack of funding (Bateman and Balmford, 2018). Examples are the Brechfa Forest Wind Farm, which has been developed by RWE Renewables (Natarajan, 2019) and the Pen Y Cymoedd wind farm developed by Vattenfall (Vattenfall, 2020). This leaves private companies with the responsibility to fulfil NRW’s roles, as during the development of the Brechfa Wind Farm RWE has promoted community engagement and nature conservation as part of a trend of ‘neo-liberalization’ (Natarajan, 2019; Haughton et al 2010). This may cause concerns for some, as for-profit companies like RWE and Vattenfall would likely prioritise profit motive over environmental goals, which can cause a conflict of interest between the private company, local councils and the Welsh Government (Biermann, 2022).

2.44 Natural Resources Wales's challenges

There can be conflicts within NRW due to cultural differences and aims between different regions in Wales and different interpretations of parts of environmental policy like the Well-being of Future Generations Act 2015. An example of this is the greater importance of the preservation of the Welsh Language in Gwynedd and Ynys Mon where there is a larger proportion of Welsh speakers compared to Cardiff or Swansea, causing less cohesion between public bodies across Wales (Jones et al, 2020). NRW must safeguard the Well-being of Future Generations as environmental conservation in Wales must be in line with the targets and goals of the Wellbeing of Future Generations (Wales) Act 2015. It can be difficult to effectively examine the effectiveness of NRW if they are only as effective as the policy they follow (Jenkins, 2018). Current Welsh government policy towards renewable energy is focused on meeting ambitious targets of net zero by 2050 (Welsh Government, 2022). However, challenges regarding these targets can occur based on the block grant formula of funding from Westminster. The 'Barnett system' calculates funding based on factors such as population in a 'needs-based' system. This limits the ability for additional funding for large renewable energy projects like the Swansea Bay tidal lagoon, by focusing on short-term needs, rather than goals for the future (Evans et al, 2021).

2.45 Natural Resources Wales and the private sector

Renewable energy projects have increasingly been outsourced to the private sector in Wales, such as the Pen Y Cymoedd wind farm to Vattenfall (Vattenfall, 2020), as a result of the current devolution system (Natarajan, 2019). Therefore, it may not be financially possible for tidal energy projects to be run by the public sector in Wales, unless there is supportive funding from elsewhere (Li et al 2024). However, collaborations between NRW have always been an important feature of public service delivery (Rhodes, 1996). NRW can provide a mutually beneficial monitoring role in private sector run tidal energy projects (Parkhill and Cowell, 2016). This was the case in the Morlais tidal stream project, where NRW produced the environmental impact assessment, taking on an environmental monitoring role, rather than controlling and developing the project altogether (Li et al 2024; Morlais, 2019). Collaborations such as these can cause disputes, due to the differences in goals and motivations (Robins et al 2017). The Morlais tidal energy project was criticised by RSPB groups for its lack of concern for bird populations in Anglesey (Kudelska, 2019). Despite the project being monitored by NRW, environmental groups and the local community were neglected, showing the difficulty in collaborations between the public and private sector in Wales (Christensen et al 2019).

2.5 Conclusion

There are many factors that can determine the effectiveness of a tidal energy project, such as financial constraints, political agendas, environmental considerations, and community involvement. The case studies discussed, such as the Three Gorges Dam, La Rance Tidal Barrage, and Shetland Tidal Array, highlight the benefits and challenges of both public and private sector-led projects. Whilst the public sector, (in this case NRW), is tasked with upholding environmental standards and community interests, it faces significant challenges, such as funding limitations (Bateman and Balmford, 2018) and operational inefficiencies, as evidenced by the recent controversies surrounding its sewage management, (Horton, 2018).

The analysis suggests that the success of tidal energy projects is not solely dependent on whether they are managed by the public or private sector. It is based on whether there are environmental regulations, effective community engagement, and has long-term sustainability planning. NRW's current struggles suggest the need for better funding and more stringent regulatory oversight to ensure that tidal energy projects contribute positively to both the environment and local communities (Lewis 2015). The question of whether tidal energy projects should be run by the public sector in Wales, requires a balanced approach that can leverage the strengths of both public oversight and private sector innovation. Collaborative efforts that combine local knowledge, technological advancements, and environmental protection measures are likely to ensure the most sustainable and effective outcomes for tidal energy development in Wales.

3.0 Method

3.1 Research strategy

The main research paradigms can be classed as positivism, realism, interpretivism, post modernism and pragmatism (Saunders et al, 2015). Pragmatism is concerned with finding a practical solution to the problem, rather than committing to a specific philosophy. A pragmatic approach puts the research question at the core and justifies the methods used to meet the end goal. Interpretivism takes into account the past experiences of participants, giving a contextual understanding (Chowdhury, 2014) and

so is useful in this study to understand the participants' perspectives on how tidal energy projects should be developed.

The research questions for this study require different research strategies and methods. The first two questions fall within the pragmatic approach, whilst the third is more interpretive as it seeks to gather evidence from the first two questions and apply this to determine the role of NRW. Therefore, the sequential nature of the research questions draws upon these two different paradigms.

3.2 Research design

A mixed methods approach was deemed the most suitable by integrating both quantitative and qualitative data in order to address the research questions sequentially. The sequences involved an initial quantitative analysis of whether tidal energy projects should be run by the public or private sector in Wales followed with a qualitative approach to examine the specific focus on NRW.
A mixed methods approach was deemed suitable for this research because some of the objectives required detailed insights. Quantitative research can help identify trends and patterns in the data, by looking at what are the priorities of the public sector in tidal energy projects and comparing this to the priorities of the private sector (Treiman, 2014). Whereas, qualitative research is naturally more exploratory, allowing for aspects of the research questions to be explored further with follow up questions (Hoepfl, 1997). The mixed methods approach helped increase the depth of understanding of the research and allowed for triangulation, which enhanced the validity and reliability of the research findings, by confirming results are consistent through the different methods (Leech et al., 2010). Therefore, this mixed methods approach gave more detailed insights by allowing the participants to share their true thoughts, opinions and feelings on the subject of tidal energy ownership (Saunders et al, 2015).

3.3 Data collection methods

Surveys were selected as the data collection method so that both quantitative close-ended questions and qualitative open-ended follow up questions could be included. This allowed for numerical data and more in-depth qualitative insights to be collected simultaneously, allowing the data to be more flexible (Cresswell and Cresswell, 2017). An online survey was an efficient way of gathering data for this study, by allowing data to be collected from a geographically disperse audience from all over Wales which reduced any regional bias (Jones et al, 2020). An online survey allowed the research participants to remain anonymous, which encouraged honesty and reduce social biases in their answers for sensitive topics such as their sector of work (Bouchard, 2016). The

online survey included scale-based quantitative questions as well as more open-ended qualitative questions, that allowed the participants to elaborate on their answers and to provide evidence for the three research questions. The scale-based questions were based on a Likert Scale to help gain quantifiable data that could be used in statistical tests in the analysis. (Nemoto and Beglar, 2014). The questions asked the participants to rate on a scale of 1-6 what they thought were the most to least important priorities or factors in the development of a tidal energy project, (1 being the most important and 6 being the least). The other quantitative questions were categorical, such as asking the participants their age, sector they work in and what role they believe NRW should take on for future tidal energy projects. These questions provided pre-written options to ensure the survey was not too over-complicated for the participants, which can help increase the number of responses (Fowler, 2013). The exact same survey was sent out to every participant in order to retain a uniform approach, which provided a consistent bias (Denscombe, 2017). Rather than committing to one certain method, this research harnessed elements of quantitative and qualitative to collect a more diverse set of data (Leech et al, 2010).

Qualitative research is naturally interpretative and to ensure that the accuracy of the research participants' assumptions cannot be separated from their own backgrounds, history and prior understandings (Cresswell and Cresswell, 2017). Therefore, it was important to consider the backgrounds of the survey participants, such as their age, sector of working and their knowledge of tidal energy by using additional quantitative questions, in order to uncover the bigger picture (Nardi, 2018). It is important to note that qualitative research is holistic, meaning that different views and perspectives are required to identify the bigger picture (Cresswell and Cresswell, 2017). This study targeted individuals that are knowledgeable within the subject of tidal energy. Including participants that work in the public sector, private sector, academia and non-profit organisations ensured different perspectives were gained from a variety of backgrounds, which mitigated biases in the responses (Barber et al, 2022; Lefever et al, 2007).

Quantitative research can be criticized for lacking contextual understanding, therefore by integrating numerical data with contextual and more detailed insights helped reveal more patterns and trends in the data, giving a more comprehensive understanding (Leech et al 2010).

Questions about what sort of role NRW should take on for tidal energy projects helped determine the most effective way NRW can be involved in future tidal energy projects. It was important to ask follow-up questions about the reasons for participants optimism or pessimism for tidal energies potential in Wales, to gain a wider depth of understanding

of the challenges or opportunities that NRW may face in tidal energy development (Smith et al 2019). The questions based on Wales were put at the end of the survey, as the survey followed a pattern of asking more broad questions at the beginning such as the participants age, where they are based and their knowledge of tidal energy as a subject. Therefore, this ensured that the participants were not initially overwhelmed with intellectually challenging questions to begin with (Nardi, 2018). This also helped set the context for what the survey would cover, helping the participants frame their thoughts and responses more effectively (Nardi, 2018). The survey finally asked questions that were specific to Wales at the end, so that they survey could remain inclusive for participants who were unfamiliar with Wales and NRW for the majority of the survey. An option for “unsure” was also essential for Wales specific questions for the participants that were unfamiliar of the tidal energy situation in Wales.

3.4 Sampling

A purposive sampling method was used for this study, in order to select the most appropriate survey participants that have a large breadth of understanding of tidal energy and tidal energy ownership models (Campbell et al, 2020). A purposive sampling method increased the likelihood of obtaining more useful data that met the research objectives. In this case, selecting specific participants who met the criteria of having a sufficient knowledge of tidal energy (Tongco, 2007). The surveys were sent out to individual participants who the researcher gauged had a sufficient knowledge of tidal energy. The survey was distributed online through contact with marine energy and renewable energy bodies such as Marine Energy Wales, renewable energy companies, local authorities and NRW. Selecting willing participants who work in the energy sectors ensured that the participants’ answers would be suitable for the study by giving insights into a sector where they have experience (Campbell et al, 2020). The survey participants were of a wide range of ages and worked in different sectors and organisations. This was a necessary way of ensuring that there was less bias in their answers and allowed for different perspectives to be heard on the topic, which helped provide a wider understanding of the topic (Palinkas et al, 2015). A sample size of 100 participants was selected, which provided a representative snapshot of the population. 100 responses were deemed as necessary as no new themes were starting to emerge from the data, towards the end of the data collection, which showed that the data had achieved saturation (Boddy, 2016).

3.5 Data analysis

3.51 Quantitative data

Exploratory factor analysis was selected as the method to analyse the quantitative data from the survey. Exploratory factor analysis is a statistical technique to uncover the underlying structure of the large set of variables from the data. It can help identify which groups of variables are related to help explain patterns and correlations within the data (Watkins, 2018). It is important to understand the reasons and the factors that influence the survey participants' responses (Yong and Pearce, 2013). For example, whether there is a correlation between the sector a participant works in and whether they consider environmental sustainability as an important factor in developing a successful tidal energy project. Exploratory factor analysis has been used in the tidal energy research field previously, by testing factors such as age and gender with public support for local tidal project developments (Hooper et al 2020). Descriptive statistics such as mean and standard deviation were used from the exploratory factor analysis which were split into two tables, one for the public sector and one for the private sector. This allowed comparisons to be made between the sectors, of the average lowest and highest scores the participants had ranked for the different variables. Which showed the most to least important factors and priorities each sector had for tidal energy development (Fabrigar and Wegener 2012). Correlation matrices were produced in the exploratory factor analysis to understand the relationships between the variables. This allowed for sector specific insights to be gained, for example if there were correlations between environmental sustainability and community support shows that a sector may see these as interconnected goals (Schott, 2016).

It was important to gain categorical data from the surveys such as the sector the participants worked in currently, in order to understand how different groups perceive tidal energy ownership systems. This further allowed for the segmentation of these different groups to allow for comparison in the data analysis (Treiman, 2014). Categorical data was used to understand the potential role NRW could have in developing tidal energy projects in Wales. The question gave multiple options where the participants were asked to tick all that apply', which was different to the previous Likert scale style questions. By collecting a mixture of categorical and Likert scale data, gives a more well-rounded analysis, by providing a clear view of the findings which can complement the more in-depth insights provided by exploratory factor analysis. By asking different types of questions can help keep the participants engaged in the survey, as if the questions were too repetitive the participants may lose interest, therefore they may not provide thoughtful and accurate responses (Wong et al 2021).

3.52 Qualitative data

A thematic analysis approach was useful in identifying patterns and themes within the qualitative data (Clarke and Braun, 2017), in this case this was used for the open-ended questions, where the participants were asked to elaborate on their reasons for their optimism or pessimism for tidal energy projects. All of the responses were given a code and collated into a spreadsheet, this was completed by hand so the researcher could become more familiar with the data (Braun and Clarke, 2006). Many responses included several codes which were collated into a spreadsheet for ease of analysis. An inductive coding approach was used which allowed the codes to be made from the ground up based on the themes, patterns and categories in the data (Alhojailan, 2012). These codes were grouped into broader themes to encapsulate the key aspects of the data (Dreyer et al 2019). Themes began to emerge in the data such as “development costs”, “environmental concerns” and “political factors”, which were some of the most common answers to the qualitative questions. Coding helped organise the data into interpretable units so that the results could be communicated clearly, which allowed the themes and patterns to be analysed (Clarke and Braun, 2017).

3.5.3 Integrated analysis

An integrative analysis was used to combine the findings from the qualitative and quantitative data for cross-verification, which helped validate the findings. Themes such as “a lack of government funding” were aligned with “availability of public funding”, which enhanced the validity of the findings. This integrated analysis gave a more comprehensive understanding of the data, by capturing in-depth qualitative insights from the follow up questions which is then supported by broader quantitative patterns (Leech et al 2010).

4.0 Findings

4.1 Quantitative data findings

The quantitative findings were split into two datasets, respondents from the public sector were split from the respondents from the private sector. This helped gain an understanding of how the public and private sector differ in what their priorities are in the development of a tidal energy project.

4.11 The main priorities of a tidal energy project

The first question that was analysed from the survey was “What should be the main priorities when developing a tidal energy project”? This question asked the participants to rank 6 different priorities that would be considered in a tidal energy project in Wales. The priorities were:

- Providing green energy
- Hitting government targets
- Boosting a local economy
- Profit
- Developing innovative technology
- Supporting a local economy

The participants were asked to rank these priorities on a scale of 1-6, 1 being the most important and 6 being the least important.

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.548
Bartlett's Test of Sphericity	Approx. Chi-Square	42.290
	df	15
	Sig.	<.001

Figure 1 Public sector KMO and Bartlett's test

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.663
Bartlett's Test of Sphericity	Approx. Chi-Square	57.769
	df	15
	Sig.	<.001

Figure 2 Private sector KMO and Bartlett's test

Initially a KMO and Bartlett’s test was carried out on SPSS, which gave a measure of the sampling adequacy, this was 0.548 for the public sector seen in figure 1 and 0.663 for the private sector in figure 2. A Chi-squared test of 57.769 for private and 42.290 for the public further indicated that the public and private sector values for were suitable for factor analysis.

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
Pri_Providinggreenenergy	1.64	1.457	36
Pri_Hittinggovernmenttargets	2.61	1.517	36
Pri_Boostingeconomy	2.81	1.191	36
Pri_Profit	5.11	1.348	36
Pri_Developingtechnology	3.36	1.355	36
Pri_Supportingacommunity	2.75	1.156	36

Figure 3 Public sector descriptive statistics

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
Pri_Providinggreenenergy	2.26	1.941	38
Pri_Hittinggovernmenttargets	3.18	1.591	38
Pri_Boostingeconomy	3.68	1.629	38
Pri_Profit	3.63	1.699	38
Pri_Developingtechnology	2.84	1.305	38
Pri_Supportingacommunity	3.66	1.419	38

Figure 4 private sector descriptive statistics

Figures 3 and 4 show the mean and standard deviation of the public sector priorities on the left and the priorities of the private sector on the right. The table shows there were 36 responses for the public sector and 38 for private sector, which gives balanced view of both sectors. The mean and standard deviation results are somewhat similar between the public and private sectors. Both sectors have placed a relatively high importance on almost all of the different priorities as all but 1 have a mean of below 5. Both tables show the main priority of a tidal energy project should be providing green energy, as these show the lowest mean value. The public sector differs from the private sector by putting a greater importance on hitting government targets, boosting a local economy and supporting a local community. This can show that the respondents working within the public sector have a greater care for wider sustainability and economic goals when developing a tidal energy project. Whereas the private sector respondents see these as a less important by-product of tidal energy development and not one of the main reasons for its development. The private sector respondents place a greater importance on developing technology and a significantly greater importance on making a profit. Profit would ultimately always be the main goal for shareholders within private sector companies (Mazzucato, M. and Semieniuk, 2018). However, it is interesting to note that even the workers within the private sector also place an importance on it being a priority. Developing innovative technology was also more important to the private sector, which may be linked to driving growth within the tidal energy market and maintaining competitive (Aslani and Mohaghar, 2013).

Correlation Matrix

		Pri_Providinggreenenergy	Pri_Hittinggovernmenttargets	Pri_Boostingeconomy	Pri_Profit	Pri_Developingtechnology	Pri_Supportingacommunity
Correlation	Pri_Providinggreenenergy	1.000	.503	.189	-.532	.097	.199
	Pri_Hittinggovernmenttargets	.503	1.000	-.043	-.398	.181	.106
	Pri_Boostingeconomy	.189	-.043	1.000	.174	.416	.171
	Pri_Profit	-.532	-.398	.174	1.000	.118	-.220
	Pri_Developingtechnology	.097	.181	.416	.118	1.000	.351
	Pri_Supportingacommunity	.199	.106	.171	-.220	.351	1.000

Figure 5 Public sector correlation matrix

Correlation Matrix[a]

		Pri_Providinggreenenergy	Pri_Hittinggovernmenttargets	Pri_Boostingeconomy	Pri_Profit	Pri_Developingtechnology	Pri_Supportingacommunity
Correlation	Pri_Providinggreenenergy	1.000	.544	.318	-.216	.337	.181
	Pri_Hittinggovernmenttargets	.544	1.000	.346	-.074	.379	.124
	Pri_Boostingeconomy	.318	.346	1.000	-.141	.472	.723
	Pri_Profit	-.216	-.074	-.141	1.000	-.137	-.110
	Pri_Developingtechnology	.337	.379	.472	-.137	1.000	.364
	Pri_Supportingacommunity	.181	.124	.723	-.110	.364	1.000

Figure 6 Private sector correlation matrix

Figures 5 and 6 show the correlations between the variables for the public sector in figure 5 and the private sector figure 5. The most significant positive correlation for the public sector was between “hitting government targets” and “providing green energy” due to these being the closest to 1.0 at 0.503. This also had a very similar score for the private sector at 0.544. This is likely due to the government targets being associated with environmental targets, as the survey question used net zero targets as an example. Therefore, the survey respondents may have ranked these priorities depending on how 'environmentally conscious’ they were. There was a significant negative correlation on the public sector table between “profit” and “providing green energy” at –0.532. It is likely from the means table that the negative correlation was from public sector participants ranking “providing green energy” as the most important priority and “profit” as the least important. Although the private sector also had a negative correlation at –0.216, this figure is far less negative, when compared to the public sector respondents. This backs up the previous table that making a profit is an unimportant factor within the public sector and a more important factor within the private sector.
In the private sector matrix, boosting the economy and supporting a community had a significant positive correlation of 0.723. This positive correlation backs up the previous mean scores, where private sector respondents ranked supporting a community and boosting the economy as the lowest importance on Likert scale. Therefore, it is likely that many of the private sector participants ranked both of these priorities, similarly, based on whether or not they believed tidal energy projects should have the interests of wider stakeholders in mind. It is interesting to note that there was little correlation on the public sector table at just 0.171, which shows a significant difference between the public

and private sector respondents' priorities in how a tidal energy project should be developed.

4.12 Most important factors when developing a tidal project

A similar approach of using exploratory factor analysis was also used for the question; "What factors are most important for the successful management of a tidal energy project"? Similarly, this question asked the participants to rank the following factors on a scale of 1-6: (1 being the most important, and 6 being the least important)

- Environmental sustainability
- Minimising cost
- Community support
- Technological innovation
- Strong regulatory framework
- Effective governance

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.530
Bartlett's Test of Sphericity	Approx. Chi-Square	28.929
	df	15
	Sig.	.016

Figure 7 Public sector KMO and Bartlett's test

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.701
Bartlett's Test of Sphericity	Approx. Chi-Square	43.859
	df	15
	Sig.	<.001

Figure 8 private sector KMO and Bartlett's test

The KMO and Bartlett's tests were repeated for the question on the most important factors when developing a successful tidal energy project. The tests were repeated to ensure that the factors were suitable for exploratory factor analysis. The KMO tests gave values of 0.53 for the public sector and 0.701 for the private sector, which showed that the values were suitable for exploratory factor analysis.

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
Fac_Environmentalsustainability	1.92	1.381	36
Fac_Minimisingcost	3.89	1.833	36
Fac_Communitysupport	3.08	1.422	36
Fac_Technologicalinnovation	3.61	1.225	36
Fac_Strongregulatoryframework	2.81	1.191	36
Fac_Effectivegovernance	2.25	1.251	36

Figure 9 Public sector descriptive statistics

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
Fac_Environmentalsustainability	3.13	1.862	38
Fac_Minimisngcost	2.71	1.505	38
Fac_Communitysupport	3.87	1.630	38
Fac_Technologyinnovation	2.87	1.563	38
Fac_Strongregulatoryframework	3.53	1.350	38
Fac_Effectivegovernance	3.63	1.584	38

Figure 10 Private sector descriptive statistics

Figures 9 and 10 show that the public and private sector differ in what factors they consider are the most important when running a successful tidal energy project. The public sector considers the most important to be environmental sustainability by having a mean value of 1.92, whereas the private sector considers minimising cost as more important at 2.71. This is likely due to the high costs of mitigating damage to the local ecosystems. Therefore, the private sector who would places a higher importance on profit (as seen in figures 3 and 4), would rank environmental sustainability as less important than minimising cost. The private sectors profit motive has also led to technological innovation being a very important factor at 2.87. Developing innovative technology can allow a private company to gain a competitive market advantage, that can allow the company to become involved more frequently in future tidal projects, by gaining recognition for their innovative technology. The public sector places a greater importance on a strong regulatory framework, effective governance and community support compared to the private sector. The private sector would want less restrictions and regulations when developing a tidal energy project, for lower compliance costs and giving more freedom to introduce new technology (Igoe, 2007). Therefore, this explains why the private sector would not see a strong regulatory framework and effective governance as important factors when developing a tidal energy project.

Correlation Matrix[a]

		Fac_Environmentalsustainability	Fac_Minimisingcost	Fac_Communitysupport	Fac_Technologicalinnovation	Fac_Strongregulatoryframework	Fac_Effectivegovernance
Correlation	Fac_Environmentalsustainability	1.000	-.331	.324	.065	-.149	.261
	Fac_Minimisingcost	-.331	1.000	-.336	.387	.252	-.087
	Fac_Communitysupport	.324	-.336	1.000	-.063	.162	.341
	Fac_Technologicalinnovation	.065	.387	-.063	1.000	.005	.009
	Fac_Strongregulatoryframework	-.149	.252	.162	.005	1.000	.245
	Fac_Effectivegovernance	.261	-.087	.341	.009	.245	1.000

Figure 11 Public sector correlation matrix

Correlation Matrix

		Fac_Environmentalsustainability	Fac_Minimisngcost	Fac_Communitysupport	Fac_Technologyinnovation	Fac_Strongregulatoryframework	Fac_Effectivegovernance
Correlation	Fac_Environmentalsustainability	1.000	-.034	.246	-.012	.445	.402
	Fac_Minimisngcost	-.034	1.000	.193	.340	.157	.419
	Fac_Communitysupport	.246	.193	1.000	.279	.351	.441
	Fac_Technologyinnovation	-.012	.340	.279	1.000	.226	.264
	Fac_Strongregulatoryframework	.445	.157	.351	.226	1.000	.510
	Fac_Effectivegovernance	.402	.419	.441	.264	.510	1.000

Figure 12 Private sector correlation matrix

Figure 11 shows negative correlations between minimising cost with environmental sustainability and community support at –0.331 and –0.336. This shows that some participants within the public sector think that additional funding towards sustainability measures such as mitigating damage to wildlife and protecting local community interests in a tidal energy project are unnecessary. This is due to the limited amounts of public funding that is available, therefore these participants believed minimising cost was more important than mitigating environmental damage and additional sustainability measures. The most significant positive correlation in figure 12 is between effective governance and a strong regulatory framework at 0.510. This suggests a group of participants from the private sector may think that the public sector should be involved in tidal energy projects, by placing an importance on both regulations and governance. It is possible these private sector participants believe in more collaborative projects between the public and private sector. This is a possibility as when the survey question was asked; “Do you think there should be more collaboration between the public and private sectors in tidal energy projects?”, 66.7% said yes. Therefore, many private sector respondents may have selected a strong regulatory framework and effective governance as important factors, suggesting the public sector could be involved in tidal projects by creating effective regulations.

4.13 Potential roles for NRW

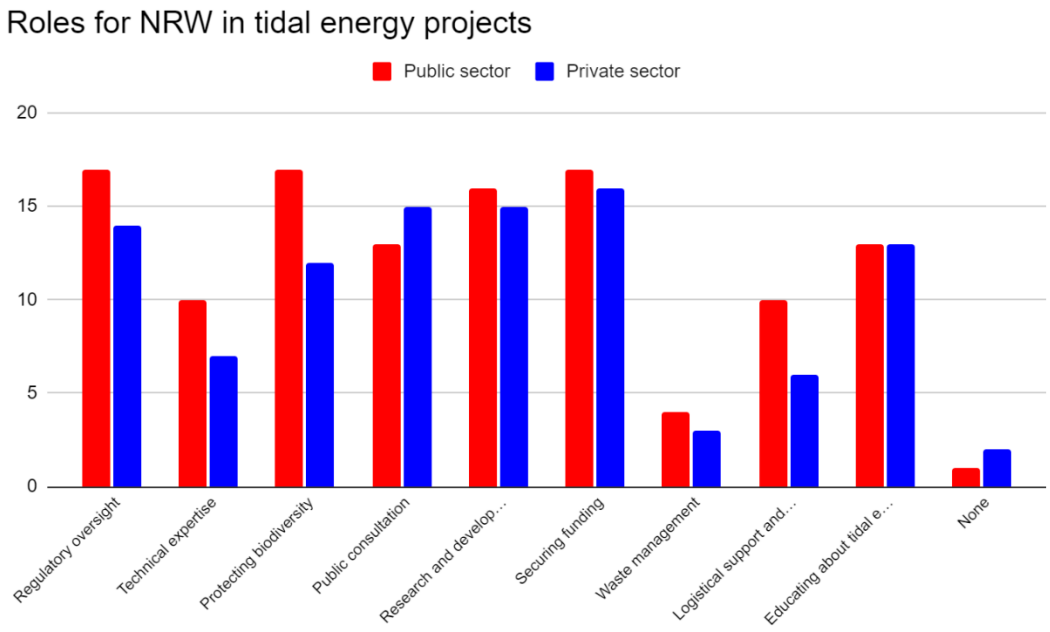

Figure 13 Potential roles for NRW bar chart

Figure 13 shows similarities between the public and private sectors in what role NRW should undertake for the development of tidal energy projects in Wales. Both sectors believe that NRW should have a responsibility to help secure funding for tidal energy projects as this was the most common response overall. This is likely because one of the most common issues raised in the survey was the lack of funding for tidal energy projects in Wales. Both sectors generally agreed that NRW should not take on a waste management role, this may have been influenced by the scandal where NRW were found to be dumping sewage into a protection dolphin habitat in Cardigan Bay (Horton, 2023). Despite there not being many differences between the two sectors views, far more public sector respondents believed NRW should have a responsibility to protect biodiversity and ecosystems during a tidal projects development. The private sector may have prioritised cost saving measures over protecting biodiversity, as suggested in figures 3 and 4 the private sector places a greater importance on tidal energy projects making a profit. Overall, it is important to note that the private sector believes NRW should have a less significant role in the development of tidal energy projects. There was a total of 117 roles suggested for NRW from the public sector, compared to 101 that the private sector had suggested.

4.2 Qualitative data findings

The participants were asked two questions that can be classed as 'qualitative', both of which were follow-up questions that asked the participants to "**Please elaborate on your optimism or pessimism about the future of tidal energy**". The other question was specific to Wales, asking the participants to "**Please elaborate on the reasons for your optimism or pessimism towards the future of tidal energy in Wales**". These questions helped give a deeper understanding of the thought process behind the participants attitudes towards the future of tidal energy, as a concept and in Wales (Cresswell and Cresswell, 2017). To analyse the qualitative data from the questions, several themes were established from the coding process. These themes were gathered as they were the most common answers to the questions (Clarke and Braun, 2017). The themes included were;

- Development costs
- Alternative renewable energy sources
- Environmental factors
- Political factors
- The private sector
- Geographical advantages

4.21 Development costs

The most common reason for the participants' pessimism towards the future of tidal energy can be attributed to its development costs being too high. 33% of the responses to the question "How optimistic are you about the future of tidal energy?" mentioned tidal energy's high development costs as a reason for their pessimism. This was the most common reason for the participants pessimism, as one participant summed this view up by writing; **"it is too expensive currently, which is unfortunate"**. High development costs were often linked with tidal energy technology being in its infancy, which can leave an element of risk that tidal energy will not be cost-effective. This viewpoint was stated by this respondent; "**I don't think it is ever going to be cost effective given uncertainties over the technology, the cost of creating it**". A small minority of 9% of the responses were more optimistic that development costs could be alleviated by private sector funding. An increase in private sector funding and switching to alternative renewable energy sources were the only suggestions of mitigating the high development costs of tidal energy.

4.22 Alternative renewable energy sources

The view that tidal energy's costs are too high was supported by participants who suggested that alternative renewable energy sources such as wind, solar and nuclear can be more effective. One participant stated that wind and solar energy "**can be far cheaper and more realistic"**. The word "realistic" can imply that the participant was referring to the high development costs of running tidal energy projects. This could suggest that alternative renewable energy sources, such as wind or solar may be more effective due to their lower cost of development, when compared to tidal. Although alternative renewable energy sources were suggested as being more effective than tidal energy, none of the participants suggested the use of fossil fuels such as oil or gas should take priority over tidal energy. Therefore, almost all of the participants agreed that renewable energy use should be expanded.

4.23 Environmental factors

18% of participants expressed concern for the damage that tidal projects can cause to marine ecosystems. Many respondents suggested this, as one respondent stated that tidal energy can be **"dangerous for wildlife and surrounding ecosystems"**. As a result of this being a common theme, it can be seen as one of the main issues with tidal energy. Despite the negative environmental impacts that tidal energy projects can cause, it was suggested technology may be able to mitigate this issue in the future. This was summed up by this response; "**although its disruption to habitats in marine ecosystems is a current issue, I believe it can be mitigated in future through technology**". This view can show there are solutions to some of the main issues that surround tidal energy, although they may be difficult to achieve. The positive environmental impacts that tidal energy can bring were also discussed by the respondents. By stating that tidal energy can be a "**clean**" and "**sustainable**" renewable energy source and an important part of Wales's renewable energy mix. Many of the participants were optimistic about the future of tidal energy in Wales due to the "**pressure of net zero targets**", that were introduced through Welsh Government legislation, such as the Wales Plan 2021-25 (Welsh Government, 2022). Legislation such as this can provide a greater urgency for tidal energy projects, if there is a necessity to meet the net zero targets.

4.24 Political factors

Many of the political based answers were critical of both the UK and Welsh governments, as 29% of responses expressed negative political themes. Many of these

responses were critical of the apathy from the Welsh government towards tidal energy, stating; "**there has been little willing from the Welsh government to build tidal energy projects**". A similar negative view was shared of the UK government, suggesting there is little willing to develop tidal energy projects as a result of its strike price. "**Strike prices need subsidy from UK government, and I don't think the Uk gov has the will or money to do this**". This pessimism towards the Welsh and UK governments may be influenced by the cancelled Swansea Bay tidal lagoon project, which was initially set to be funded and run by the UK and Welsh governments (Vaughan, 2019). Other participants had more optimistic politically based answers, which were timely due to the UK general election taking place at the same time as when the survey was sent out, which led to a change of government (Cracknell et al 2024). A participant showed their optimism by stating **"With the return of a Labour Government in Westminster, and the Welsh Government's environmental policies, surely we should be more optimistic"**. However, another participant suggested that the new labour governments lifting of the ban on onshore wind farms may lead to more funding being allocated to wind energy, rather than tidal (Horton, 2024).

4.25 The private sector

High development costs and political factors were some of the most common reasons for the participants pessimism towards the future of tidal energy in Wales and as a concept. This thinking led to responses that private sector involvement may be necessary to alleviate funding concerns and kickstart future tidal energy projects in Wales. This can be summed up by the quote; "**more funding is needed which could be secured from private companies**". However, it is difficult to find out whether these responses had a generally favourable view of private sector involvement in tidal energy projects, or whether it may be "necessary" to solve the current public sector funding issues. This view was supported by the apathy shown from the Welsh and UK governments towards tidal energy, where the Swansea Bay project cancellation was used as an example, the Swansea project is now looking for alternative private investment in order to restart the project (Youle, 2023). Negative views of the private sector were shared as many respondents believed that renewable energy projects are being "**constantly outsourced to the private sector**". There was also concern that private companies would be too focused on profit, which was suggested as being detrimental to the tidal project's development. One participant summarised this view by stating "**I do not believe that upcoming tidal projects will be effective if they are in the hands of private companies solely building the development for profit**".

4.26 Geographical advantages

The majority of participants optimism about the future of tidal energy in Wales was based around Wales's geographical potential for tidal energy. 18% of participants stated Wales has potential to harness tidal energy in the future due to the "**large tidal ranges"** in "**Swansea Bay**" and the "**Severn Estuary**". This led to one participant suggesting that Wales could become a **"world leader"** in the tidal energy field in the future, due to the naturally high tidal ranges (Roche et al, 2016). Despite this suggestion being a long-term aspirational goal for tidal energy in Wales, this can show that tidal energy can thrive if it is run effectively. The geographical advantages in Wales were often linked with the consistent supply of energy that tidal energy provides, a participant summed this up by stating that tidal energy; "**provides a consistent supply of energy that can be harnessed effectively in Wales**". This comment supports the previous comment of Wales having the potential to become a "**world leader"**, by harnessing the large tidal ranges in Wales with the advantageous consistent supply of energy that tidal energy provides.

5.0 Discussion

5.1 Introduction

The survey was designed following the literature review and then the findings were presented around the qualitative themes and statistical analysis. The analysis provides a benchmark to examine the evidence in the literature review. The discussion starts with an examination of the evidence for each part of the research question.

5.2 Public vs private involvement in tidal energy

One of the main themes in the quantitative data was that the survey participants from the public sector placed a far greater importance on tidal energy projects contributing to wider sustainability goals, that protect public interest. Whereas the private sector respondents prioritised profit and technology innovation, which are essential for business growth and market competitiveness. These views can be backed up by the literature view, as in Norway, local governments place an importance on community sustainability goals within decentralised environmental projects (Falleth and Hovik, 2009). It is far easier to contribute to sustainability goals in a smaller, local environmental project compared to a larger project that will have nationwide impacts (Naylor et al, 2019). Therefore, in a large tidal project in Wales such as the proposed

Swansea Bay tidal lagoon it may be difficult to prioritise local wildlife and communities when the project affects a wider population, in this case Wales as a whole, leaving these issues to be neglected (Wu et al 2020). This issue occurred in the Three Gorges Dam project in China, where there was concern of the project harming the endangered freshwater dolphin species, however this can seem insignificant when the project is designed to produce renewable energy for the large Chinese population (Hance, 2008). Damage to wildlife and ecosystems can be mitigated through innovative technology, which was a factor that was prioritised by the private sector respondents. The privately run Shetland Tidal Array project used innovative technology in its energy converters, to mitigate damage to marine ecosystems (Santos-Herran et al, 2019). The Shetland Tidal Array also introduced a 'community owned' turbine, designed to raise awareness about the benefits of renewable energy within the Shetland community (Mirzania et al, 2019). However, measures such as this can be criticised for being insignificant and a case of 'greenwashing' (Grove and Clouse, 2013). Rather than meaningful funding that could be put into the Shetland community (Hinton, 2020).

There can be benefits to collaborative projects between the public and private sectors, by using private sector funding for innovative technology to be introduced, which can mitigate the environmental issues that occurs in tidal energy projects. In the survey 66.7% of participants thought there should be more collaboration between the public and private sectors in tidal energy, showing an appetite for collaboration across both sectors. Funding was one of the main reasons for participants pessimism towards the future of tidal energy which has been a recurring issue in Wales regarding NRW (Bateman and Balmford, 2018). Private investment has mitigated funding issues previously in Wales such as the Vattenfall Pen Y Cymoedd wind farm (Vattenfall, 2020). Profit was a far more important priority from the private sector respondents, but this could result in hindering the long-term sustainability of projects unless there is adequate reinvestment of finance back into the tidal project, which could be dependent upon shareholder priorities (Clark, 1973).

5.3 Driving factors

The most important driving factor in the development of tidal energy projects for both the public and private sectors was to 'provide green energy'. Both the public and private sectors therefore share similar goals, in wanting to reduce carbon emissions and mitigate climate related issues through the use of renewable energy. However, the private sector differs significantly from the public sector due to the profit motive (Jurkiewicz et al, 1998), which can lead to cost cutting measures in the tidal projects

development to increase profit (Hinton, 2020). This was the case in the Belo Monte hydroelectric dam in the Amazon, where a private company prioritised capital gain over basic preservation of ecosystems and communities, leading to displacement of marine habitats and indigenous communities in the Amazon (Fearnside, 2017). This was allowed as a result of then Brazilian president Bolsonaro's overly relaxed measures, which neglected any sort of environmental conservation (Deutsch, 2021). This issue can be mitigated through a 'strong regulatory framework', by enforcing environmental standards such as detailed environmental impact assessments. This can prevent shortcuts from being taken that could damage ecosystems as a way of reducing expenses (Beatley, 1989). These measures have been used in collaborative projects in Wales. In the privately run Morlais tidal stream project, NRW took on an environmental monitoring role by producing the environmental impact assessment, which aimed to mitigate damage to local biodiversity and to help support communities on Holy Island (Li et al 2024; Morlais, 2019). Therefore, collaboration between the public and private sectors has potential to be effective, as long as the public sector can some sort of regulatory role, to mitigating negative impacts on ecosystems and communities. Despite the potential for the private sector to cut corners for the sake of profit, it is not in their best interests. For example, a tidal project that causes damage to marine wildlife would break the Wildlife and Countryside Act 1981 (UK Government, 1982) which could gain mass media attention and damage the brand image of a private company (Aslani and Mohaghar, 2013). This has been the case previously in Wales where a petition was made to put a stop to the Morlais tidal project due to the potential harm caused to local bird populations (Kudelska, 2019). Therefore, the profit motive can be beneficial in some circumstances, by providing deterrents which prevent the private sector from causing significant environmental damage.

Despite the pessimism surrounding funding issues in Wales, the main reason for optimism was Wales's geographical potential for tidal energy, due to its high tidal ranges in areas such as Swansea Bay and the Severn Estuary. This was a far more common answer than other suggested driving factors. High tidal ranges in Wales can serve as a strong driving factor for both sectors by providing an opportunity to maximise renewable energy production, which can provide a high energy yield (Shetty and Priyam, 2022). Another common driving factor for both sectors was that tidal energy can provide opportunities for job creation and economic development in Wales. This can be beneficial for both the public and private sector, as the Welsh Government can offer additional funding in the form of grants to boost the development of tidal energy projects, to create jobs and hit government net zero targets (Smart, 2007; Welsh Government, 2022).

5.4 The role for NRW in tidal energy

Both the public and private sector respondents believed NRW should play a significant role in the development of tidal energy projects. Therefore, this showed a degree of trust in NRW from the private sector, further bolstering the argument that collaboration between the sectors is possible. The consensus was that NRW should have a large role in providing regulatory oversight and protecting biodiversity. By carrying out this role, NRW can mitigate some of the main issues with tidal energy projects, which is the negative impacts it can cause to nearby ecosystems and wildlife (Viehman and Zydlewski 2015). Regulations can come in the form of environmental impact assessments and monitoring programmes, which is a role NRW have previously carried out in the Morlais tidal stream project (Morlais, 2019). It was suggested NRW could have a role in education and public consultation, which can be essential in mitigating the issue of 'nimbyism', by keeping the public informed about the positive opportunities tidal energy can bring. This can be a significant factor in slowing down the development of tidal energy projects due to opposition from local communities, which was also suggested by the participants in the qualitative data (Van der Horst, 2007).

It was suggested NRW could have a role in helping with tidal energy funding and research, despite funding and technology innovation being associated with the private sector in previous survey questions. NRW can still have a role in securing government grants as a part of a collaborative funding effort. Collaborative funding and research from both sectors, can symbolise the joint effort between the public and private sector. It can also ensure funding is given to the environmental and social goals of the public sector, as well as market-based goals of the private sector, which can lessen disputes between the sectors (Robins et al, 2017). One of main concerns with NRW is its lack of funding (Bateman and Balmford, 2018). Funding for NRW may need to be increased if they are going to have a significant role, such as the ones suggested in a large tidal energy project. Otherwise, there is a risk of inadequate environmental monitoring which has occurred in previous projects NRW were involved in such as the Morlais project and the sewage spilling in Cardigan Bay (Coles et al, 2021; Horton, 2023).

Collaboration between NRW and the private sector is not a new concept and has been a common part of renewable energy development in recent year. Examples of this being the Morlais tidal stream project and the Vattenfall wind energy project (Morlais, 2019; Parkhill and Cowell, 2016; Rhodes, 1996; Vattenfall, 2020). Therefore, collaboration between NRW and the private sector may be an essential part of delivering larger tidal energy projects in future, to alleviate issues such as cost, environmental damage and gain the support of communities.

6.0 Weighing up the evidence

The findings from the survey, alongside backing from the literature review suggested that tidal energy projects in Wales should be run as a collaboration between the public and private sectors. The literature review suggested that the public and private sectors can differ slightly in their goals when it comes to the development of a tidal energy project (Jurkiewicz et al, 1998). This claim was supported in the quantitative data, where the public sector respondents believed tidal energy projects should benefit wider stakeholders, by proving job opportunities and support local communities. Whereas the private sector prioritised goals that were mainly driven by profit, such as technology innovation and building their brand image (Jurkiewicz et al, 1998). The profit motive can be detrimental to tidal energy projects in some circumstances, as cost cutting measures can lead to environmental monitoring being neglected for the sake of short-term profit gain (Biermann, 2022). Therefore, this reinforces the need for effective public sector involvement in tidal energy projects, to act as a regulatory body, to ensure tidal energy projects are sustainable in the long-term (Jenkins, 2018).

The public sector, represented by entities like NRW, should play a crucial role in ensuring that tidal energy projects align with environmental regulations and community interest, which are some of the main issues that can hinder the progress of a tidal energy project (Polagye et al, 2011; Van der Horst, 2007). The findings from the quantitative data backed this claim, the public and private sector respondents both supported a plethora of roles that NRW should be involved in. However, one of the main concerns with the public sector in Wales from the qualitative data was the lack of funding that is available. In the past this has significantly limited NRW's ability to be a regulatory body for effective conservation (Bateman and Balmford, 2018; Horton, 2023). Private sector investment may be necessary, in order to ensure tidal energy projects are sustainable in Wales and reduce the financial risk of undertaking tidal energy projects. The profit motive can be necessary to help drive cost-effective solutions, which helps mitigate the cost issue of tidal energy projects (Mazzucato and Semieniuk, 2018). The profit motive can be beneficial in driving technology innovation to remain competitive within the renewable energy market, such as the case in the privately run Shetland Tidal Array project (Santos-Herran et al, 2019). Neither the public nor private sector can independently address all of the challenges associated with tidal energy development in Wales. Collaboration between the public and private sectors can leverage their respective strengths and aims, to ensure that tidal energy projects are developed to be economically viable and environmentally sustainable.

7.0 Recommendations

The primary aim of the study was to critically examine the role of the public sector for the development of tidal energy projects in Wales. This was achieved, it was found following the findings that NRW can take on a plethora of roles that were supported by the respondents in the quantitative data. The most significant role NRW should take on is a regulatory role, by ensuring that tidal energy projects are environmentally sustainable, and its benefits are shared across wider stakeholders and communities (Sullivan, 2013). The survey data helped discover that private sector involvement is also necessary to help alleviate funding issues in Wales, which was one of the main concerns of tidal energy development in Wales in the qualitative data.

The benefits and challenges of each sector were explored in the literature review. The public sector can be beneficial by typically prioritising public interest, leading to more sustainable practises and a focus on minimising negative social impacts (Naylor et al, 2019). However, there can be issues when catering towards mass public interest that certain stakeholders that are deemed ‘less important can be neglected, such as in the case of the Three Gorges Dam project, where protecting ecology was not prioritised in order to design a large project that fit the needs of the large Chinese population (Li et al, 2013). Whereas the private sector can be useful in using private capital from investors to help kickstart the development of tidal energy projects. The private sector can also be beneficial in developing innovative technology, which can be driven by the profit motive (Santos-Herran et al, 2019). Therefore, despite the differences in aims between the sectors, a collaborative effort can mitigate several of the issues that are associated within each sector.

The quantitative data found that the most significant driving factor behind public sector involvement in tidal energy was to provide ‘green energy’. This can be linked with the Welsh governments environmental targets such the Wellbeing of Future Generations (Wales) Act 2015, which emphasise the importance of renewable energy to reduce carbon emissions (Welsh Government, 2015). The private sector also found this to be the most important driving factor in the quantitative data. However, the private sector respondents placed a much higher importance on profit compared to the public sector. The private sector’s profit motive emphasises the need for NRW to act as a regulatory body in tidal energy projects, to prevent private companies from taking shortcuts on sustainability measures, for the sake of minimising cost (Segura et al 2017). NRW can ensure that tidal energy projects are environmentally sustainable and within the best interests of the public and communities by acting as a regulatory body. This will help ensure the success of tidal energy projects in the long-term (Withers, 2021).

8.0 Limitations

The research for this study was mainly conducted by participants in Wales and other parts of the UK, as the study focused on NRW's potential involvement in tidal energy projects in Wales. If this study was to be built on further, insights could be gained from other countries' potential for public or private ownership of tidal energy in a more global study, to broaden the geographic scope. A global study would need to consider the differing cultural and socio-economic factors of other countries (Shortall and Kharrazi, 2017). By gaining an understanding of how the differences in marine ecology, cultural attitudes towards public ownership and different socio-economic conditions could influence the success of a tidal energy project (Urmee and Md, 2016). By incorporating insights from other countries, this study could provide a more comprehensive understanding of the optimal way to develop tidal energy projects. This could help identify more universal principles and strategies for tidal energy, that could be applied beyond Wales.

In the survey, a question asked which sector the participants currently work in, which was used to show the differences in responses between the public and private sectors. Therefore, it was not taken into account how long each participant has worked in each their certain sector. For example, a participant may have worked in the public sector for 20 years and recently moved to work within the private sector, which could affect their thinking in their answers. Compared to a participant who has only ever worked within the private sector. This may have led to anomalies in the data, where a participants' answers did not correlate with the other participants working in the same sector (Bethlehem, 2010). If the study was to be conducted differently, a scale option could ask the participants how many years they have worked in their respective sectors. This could provide more accurate views of what factors the public and private sectors prioritise in tidal energy projects. By reducing the risk of overgeneralising the findings to all public and private sector professionals.

A sample size of 100 respondents was used for this study, 36 were from the public sector and 38 were from the private sector, the rest of the respondents worked in academia, non-profit organisations or were not currently in full employment. A larger sample size can make the study more reflective of the population and more generalisable, reducing the impact of outliers and anomalies in the quantitative data. A more diverse and representative sample could better capture the full range of perspectives and opinions in the qualitative data (Andrade, 2020). Although there was a slight imbalance between the public and private sector respondents a difference of 2 responses, this imbalance would be lessened if there was a larger sample size. Increasing the sample size can improve the quality and reliability of exploratory factor

analysis, by reducing the risk of sampling error and allows for subtle patterns to be detected in the data. This would increase the score given in the KMO and Bartlett's test, showing the data is more suitable for factor analysis (MacCallum et al, 1999).

9.0 Conclusion

This study set out to find the optimal method of developing and running tidal energy projects in Wales. This was inspired by the Swansea Bay tidal lagoon proposal which was initially set to be run by the public sector, but this was cancelled by the UK Government due to funding limitations, resulting in the project being potentially run by the private sector (Youle, 2023). This study set out to find out whether this would be beneficial, as the Welsh Government has set plans on expanding Wales's renewable energy mix in legislation such as the Future Generations (Wales) Act 2015 (Welsh Government, 2015). Secondary research aims were set out to discover the benefits, challenges and driving factors behind public and private ownership of tidal energy projects, which allowed a potential role for NRW in tidal energy projects to be discovered.

The literature review identified that there were gaps in research around public and private ownership of tidal energy. Previous studies on public and private ownership in water conservation (Kallis et al, 2010), are similar and helped establish the context and theoretical framework of the research. The literature review examined the success of previous tidal energy projects, such as the publicly run La Rance tidal project (Kirby and Retière, 2009) and the Shetland tidal array project (Carrell, 2016). These examples showed both public and private tidal projects have the potential to be successful if run effectively. The effectiveness of NRW was also examined, to gain a context of NRW's benefits and limitations, in order to understand its potential role in tidal energy development. It was important to understand what previous research had discovered in terms of the benefits, challenges and driving factors behind different ownership models of tidal energy. This helped inform the research design of this study by identifying gaps in current research.

The study used an online survey, to gain an understanding of what the differences in priorities were for the public and private sector respondents in a tidal energy projects development. The survey used Likert scale type questions where participants ranked factors based on their importance, such as environmental sustainability, community support and technology innovation. This showed the similarities, differences and driving factors behind the public and private sectors (Nemoto and Beglar, 2014). Open-ended questions were also asked, allowing the participants to elaborate on their answers (Cresswell and Cresswell, 2017). This mixed methods study of integrating quantitative

and qualitative allowed a flexible approach for the data collection and gave detailed insights, which helped answer the research questions (Treiman, 2014). The study used exploratory factor analysis and coding methods to analyse the findings from the survey. This allowed for themes and patterns to emerge, to show the driving factors and priorities of the sectors, which helped establish a potential role for NRW (Watkins, 2018).

The data showed that the aims of the public and private sector were relatively similar, whilst the public sector put a slightly greater importance on tidal energy projects benefitting wider stakeholders such as local communities and environmental sustainability. Whereas the private sector put a greater importance on market-based goals such as profit and innovative technology. Despite their differences in aims, collaboration between the public and private sector was decided as the optimal solution to develop and run tidal energy projects in Wales. This was decided following the findings from the survey data, where cost and a lack of funding was raised as the main concern with tidal energy in Wales, an area the private sector could mitigate with private capital investment (Mazzucato and Semieniuk, 2018). This led to the suggestion that NRW should carry out a regulatory role in tidal energy projects. This is essential to ensure the private sector do not cut corners on sustainability measures for the sake of financial gain (Clark, 1973). Therefore, collaboration between the sectors can help drive innovation, support economic development, ensure sustainability and build public trust. Both sectors can contribute to developing the successful and sustainable tidal energy projects in Wales.

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