How do newly emerging renewable maritime energy technologies shape the structure of energy governance networks in the EU?

by

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1. Introduction: The maritime sector and maritime energies

In 2021 the United Nations originated the "Decade of Ocean Science for Sustainable Development", a decade that is ought to connect people with the ocean. With sustainability at the heart of scientific research, it aims to focus on transformative solutions for the ocean. The ocean deserves this scientific acknowledgement as climate change and its mitigation are unequivocally connected to it. Absorption of CO_2 and climate regulation are necessary for a well-functioning planetary ecosystem, which makes the ocean one of the most environmentally important assets. At the same time, the ocean is threatened by human induced climate change, leading to acidification, CO_2 release and the rise of sea levels. Clearly, the ocean is at the pivot point of positive and negative implications for the future of our blue planet.

The long European coastline reveals many opportunities for interaction with the ocean and puts the European maritime sector into focus for future transformative development. According to the International Labour Organization, interactions with the ocean in the maritime sector are mainly shipping, fishery, ports, and inland waterways. (International Labour Organization, last time accessed: 05.09.2023). Each of the sub-sectors can be the target for enhancing sustainability measures, e.g., fuel efficient shipping trade or maintaining biodiversity while fishing. Moreover, as an additional sub-system of ocean instrumentalization, technological advancements may offer novel ways of using the ocean for energy provision. Generating energy from the ocean combining all offshore renewable energies can be called maritime renewable energy (MRE). This includes ocean energy (tidal, wave, geothermal, salinity gradient) as well as marine energy (offshore wind, floating wind). Some MRE solutions like offshore wind parks are being scaled commercially, whereas other technologies are still in its initiate stage. Yet, many pilot projects already create promising results in the emergent sector of sustainable ocean energy. These are all opportunities the EU may exploit.

MREs can be understood as an important asset for the EU to proof itself in its sustainability aspirations and incentivize governance in favor of these emergent technologies. Governing MREs is far from easy, as ocean and energy governance both resemble significant unique traits. As far as other sub-sectors like fishing or waterways are concerned, it is prevalent that MREs like wave farms need space which often collides with other legal obligations the sea fulfills due to its openness character, where the sea is first and foremost an open space (Michalak, 2018). With offshore expansion to commercial MRE projects, privatization of the sea and the obstruction of other maritime-subsectors, legal difficulties may arise. Many scholars emphasize on this issue in the sphere of ocean governance, where the characteristics of such legal embeddedness are completely different to land use (Tebar, 2018). Solutions like a Multipurpose Marine Cadastre are put forward to resolve certain conflicts, trying to connect the legal ambiguities, making them more coherent (Michalak, 2018). Ocean governance is connected to different dimensions, for instance when examining the distance away from the coastline or by examining the seabed, surface, or the water body itself (Tebar, 2018). MREs can have a lot of different overlaps in some dimensions, for instance when specific tidal arrays must be connected to the seabed but reach out in the water body. It can be derived that ocean governance is opaque, dependent on dimensions and multiple variables. The other part of the spectrum, energy governance, does also come with its specific difficulties.

Researchers report a governance landscape that is mostly fractured. They see issues in geopolitical dependencies, no overarching regulatory bodies and the effect of sustainable transitions creating tensions between providers using fossil fuel technology and emerging technologies (Apolonia et al., 2021; Eicke & Petri, 2020; Florini & Sovacool, 2009; Lange, Page, et al., 2018; Neukirch, 2019; Wilson, 2018). Governing energy is an issue that is very close to the citizen, as a rise in prices and energy poverty can quickly set implication for the core well-being of an individual. This trend is visible in the sky rocketing energy prices in times of crisis, where citizens' income is eaten up by such developments, leading to energy poverty (Strünck, 2020). Governing energy and governing the ocean is also influenced with the technological advancement and innovation of MREs. Scholars of innovation and technology resemble broader connectedness to the scope of political economy and international relations. Here, innovation is put in connection with resource allocation and power shifts (Drezner, 2019). Therefore, from a perspective of innovation, one could encapsule MRE developments as an innovation ecosystem, which is defined by Granstrand & Holgersson (2020): *„An innovation ecosystem is the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors.".* This definition puts forward the thought of actors and their interconnection, which creates a system of actors and relations, an approach that could come in favor for examining MRE actor structures.

The three aspects- ocean, energy, and innovation governance- create a symbolic Bermuda triangle of governance difficulties. In order to not get lost here, MRE scholars are destined to decipher the complexity of the issue. They found specific legal barriers or enablers of MREs, tried mapping out structures, made status reports, established a holistic SWOT analysis, tested MREs' economic feasibility, and monitored developments, only to name a few approaches. It is prevalent that the studies are mostly hands on, connected to the private sector, calculating implementation possibilities, and engineering perfect fit solutions. Scholars from the field of energy governance rely on mapping the issue from the perspective of international political economy and international relations, examining a fractured landscape in global energy governance. In the EU, a handbook was published, which also grants insight in these fractured landscapes, for instance the chapter of patterns of stability and change by Neukirch (2019). In the work of Apolonia et al. (2021), specific barriers and enablers can be found. Even though these scholars bring up new insights in the field of MREs and its surroundings, there seems to be a lack of structure and order in the system, which makes rendering MREs as an innovation ecosystem difficult. This is what Guerra (2018) wants to address in her work, creating an oversight of the MRE landscape.

Put together with governance approaches, Guerra (2018) collects actors of MREs with different governance ambitions and sorts them according to their character, constituencies, spatial scope and subject matter (Guerra, 2018). This is helpful for a first overview of actors in the field of MREs and again gratifies the issue of governance fragmentation, not only generally in global energy governance, but in MRE governance as well. Guerra (2018) successfully presents the polycentricity of the issue in a visible way.

The research does not go beyond this point and only presents one snapshot of actors and institutions, which does not create a comparable body nor specific patterns of actor relations. This paper goes one step further and seeks to visualize MREs in two different periods of time with a network development approach. According to Carpenter et al. (2012) this approach is one of four main approaches done in social network research. Distinctions are made in the causality chain, whether the network influences an actor (person or organization) leading to social capital research or whether the network itself is concern of research, differing on the interpersonal or interorganizational level. The latter is the case in this paper, where the visualization of an interorganizational network is then also the source of analysis, carving out actors, relations, and patterns. The governance structure can therefore be understood as a network which encapsules different public and private actors being in a specific constellation to one another, portraying patterns of characteristics, leading to interpreting more fractured or cohesive developments.

Further investigating in this research is relevant because it acknowledges issues that quickly move beyond MREs. As already embarked on, MREs can be distilled to more general issues like how oceans and energy are governed and how technology advancements may indicate changes in patterns of network structures. Fostering research in this matter resembles opportunities for governments to understand patterns of energy actors, which can lead to clarification of a governance structure that is proven to be fractured. Interpreting the issue more broadly can present MREs as an example of innovative technologies in times of needed sustainable transitions, inflicted by governance issues and frequent uncertainty. A network development analysis can therefore help to clear up uncertainties and visualize complexity in a way that makes seeing governance issues and actor patterns clearer. Understanding actors, their role in the whole system, their characteristics, and possible cohesive developments, presents a relevant approach to opaque actor systems, moving beyond single use cases in MREs. This makes the paper not only important for researchers in MREs, but to scholars that are generally interested in the development of sustainable transitions in networks. Policy implications can be derived from decision makers, knowing which actors are connected to whom, what key patterns are that could develop further in the future and generally examining a trend of cohesion or fragmentation between the actors. The behavior of decision makers towards emergent technologies could make estimating the best choice for policies difficult. This paper can help removing uncertainty and creating an approach towards technological advancements form a network perspective, which enables decision makers to take a step back and understand overarching patterns and interconnections, easing their approach in forming an encompassing future driven decision for MRE development.

1.1 Research Question

When governing emergent innovative technologies like MREs, it renders the question of actors, their accountability, or sovereignty versus private companies pushing certain technologies (Zohar et al., 2022). Setting boundaries for innovation could then be an effective method to regulate its impact. Dependent on uncertainty, restrictive policies may pose a cautious approach for policy makers. Developments in renewable energy provision are currently one of the most demanded ones, as climate mitigation and therefore the reduction of emissions is deeply connected to energy consumption and its production. MREs therefore pose a promising field of innovation that entice the technology doctrine for fighting climate change, which is easily adaptable and justifiable by politicians. MREs are therefore welcome to unlock new potential in the maritime as well as the renewables sector. Yet still, as put forward above, fragmentation of energy governance is prevalent, combined with opaqueness of ocean governance, which could make governing MREs difficult. On the one hand there is the innovative force of MREs, with its great potential for energy provision. On the other hand, there is a fragmented energy governance system which is in flux about moving renewable energies forward. To unravel this complexity, a network is created, which examines actors of the field, its relations, and patterns. To assist in the examination, the following research question is the key concern of the work:

RQ: How do newly emerging renewable maritime energy technologies shape the structure of energy governance networks in the EU?

The direction of this paper is in line with the character of interorganizational network development research as put forward by Carpenter et al. (2012). Here, the network, or as put in the research question the "structure of the energy governance network", is the material of analysis and used to interpret patterns and actors. This is different to the social capital approach, where the network is causally driven as one impact factor for organizations to generate value for them (Carpenter et al., 2012). In this paper, the network is the material to be analyzed, which is influenced by emerging renewable marine energy technologies.

For creating the empirical network, the Tethys database is used. The database is provided by the Pacific Northwest National Laboratory, the US Department of Energy, Wind Energy Technologies Office (US) and the Water Power Technologies Office (US). Its efforts are collecting research and reports of MREs, which then create a database for researchers and the industry to track progress and draw new innovative solutions in a sustainable way. Moreover, the database includes metadata, supporting reports, relevant papers, and other material to provide a current state of knowledge of environmental effects. Especially important is its emphasis on the knowledge base. Here, they mainly focus on four elements: Marine Energy, Wind Energy, international collaboration focused on the environmental effects of marine energy (Ocean Energy Systems-Environmental, and international collaboration focused on the environmental effects of wind energy). Especially MRE reports and the collaboration focus are meaningful for this research, which makes the databases' material sufficient for assessment, creating a network which can display actors and their constellations to one another. Emphasis is put on two main technology categories, being marine energy and wind energy. For marine energy, they encapsule Ocean Current Energy, Ocean Thermal Energy Conversion, Riverine Energy, Salinity Gradient Energy, Tidal Energy and Wave Energy. For Wind Energy they examine Land-Based Wind Energy, Fixed Offshore Wind Energy, and Floating Offshore Wind Energy. For this assessment, reports were filtered to examine MREs only (filtering out reports on Land-Based Wind Energy), focusing on Europe and its causes for human interaction, a filter that can be set in the database. This way, projects of innovation can be carved out, discarding mostly environmental impact assessments, as they do not directly display innovation reports.

Narrowing down the research was needed because of the size of the database and to focus on results that can be interpreted. A more targeted approach grants more precise understandings on the relations of the MRE system and its actors, which is important for setting boundaries of the network. This database encapsules a great number of reports tailored and constantly monitored by experts, which makes it reliable and tailored to the issue to be examined. As the database only collects MRE issues, it cannot provide a broad picture of energy governance reports and actors. There are also other databases, which would make the research more extensive, yet also distort the analytical information value when mixing them, which could lead to duplicates and subjective inclusion of reports and databases. Focusing on this database and deriving its actors from its collected reports grants possibilities for comparison and tailored statements.

The term MREs can be understood as the previously defined MREs, which resemble all kinds of offshore energy. This is typical for such a new technology and many scholars put together these technologies, sometimes under different names like Offshore Renewable Energies (OREs) (Guerra, 2018), Ocean Renewables, or Marine Renewable Energies. The character of MREs and its accelerated innovation capabilities render possibilities to connect them with innovation theory and turn them into influencers of the structure of the network. Understanding the material of analysis, which is the network, certain sub questions are carved out, that lead to answering them first theoretically and empirically, which explains what can be understood as the structure of energy governance networks. This way, an encompassing answer to the main research question can be formulated. The first sub question focuses on the network by finding out its actors:

SQ1: Which public and private actors are involved in the governance of MREs at the EU level?

By answering SQ1, the actors are carved out which enable a network to exist. Due to the broad examination possibilities, a first boundary of the network is to only focus on energy actors that are connected to MREs and not to the whole network of energy actors in the EU, as this would go beyond the scope of this research and create too broad assumptions. Theory answers questions of involvement, resource dependency, resource flows through innovation and actor characteristics and their capabilities. This way actors can be theoretically classified, connected to specific typologies. Empirically, actors are collected with the help of the Tethys database, which enables creating the network throughout the empirics. The second sub question then goes one step further and examines the structure of the network:

SQ2: How does the structure of the actors involved in the governance of MREs look like?

Here, the constellations and relations between actors are pointed out, which in a broader picture shows the structure of the network. Theoretically, the question leads to structures and cooperation between actors, influenced by innovation. Theory on innovation ecosystems, fragmentation and coherence is put forward. In addition, it is theoretically examined, how governance modes may influence public-private actor relations. Empirically, constellations between actors are examined. This allows to understand, where actor constellations are either more fractured or dense. At last, the third sub question examines the patterns of such constellations between actors.

SQ3: What are the patterns between different actors that are visible in the actor network?

The last step interprets the empirics mostly, takes a step back and interprets the actor characteristics with its specific configurations. Some theory provides insight in network patterns of the system and how a fragmented system can have different implications for top-down governing, examining variables like geopolitical dependencies, political ideologies, and private stakeholders.
After answering each of the sub questions theoretically and empirically, the main RQ can be answered by explaining, the influence of MREs on networks, presenting its actors, their constellations, and patterns. Discussions on the results and an outlook present possible ambitions for further research.

2. Setting a framework for maritime energies in the political sphere

The first theory of this paper is connected to the terms used, and explanatory concepts which are needed for answering the research question and its sub questions accordingly. This way, possible theoretical examinations can be compared with the empirical assessment. In the following, the framework for maritime energies in the political sphere is put forward, explaining its terms and definitions, creating clarity for the next steps, homing in on the issue at hand, setting up a theoretical framework for examination.

Transitioning towards MREs and advancing its technologies can stimulate changes in the economic, social, and political sphere. The focus of this paper is on the *political* sphere, which cannot be seen isolated from other aspects, yet sets the stage for the framework to be carved out. In connection to network development research, the political sphere includes actors to create a system that establishes a mix of public and private actors. These actors may have different characteristics and resources, which leads them to interact with one another and create resource flows between them, leading to dependencies. In that light, resource dependency theory (RDT) is used to explain cooperation between actors and its dependency characteristics. RDT has been established by Pfeffer and Salancik (1978) and can be defined as the following: *"RDT characterizes the corporation as an open system, dependent on contingencies in the external environment"* (Pfeffer & Salancik, 1978 in Hillman et al., 2009). Therefore, dependency to external environments is key for understanding organization dependencies and hence structures of a network. This approach resembles the core for examining the material connected to the structure of energy governance networks. Through the possible interrelations between actors according to their resources and dependencies, a structure of energy governance can be carved out, which enables theoretical concepts to connect with the examination of the structure, in this case network theory. This theory cannot be clearly defined, yet sets aspirations in sorting actors in specific ways that create a network which leads to *" (...) enhanced learning, more efficient use of resources and increased capacity to plan for and address complex problems (...)"* (Provan & Kenis, 2008). Dependent on the dimensions of the paper, scholars are either seeing the network as the material of analysis or see an organization in a network as the subject of research (Carpenter et al., 2012). Scholars like Gulati (1995) connect RDT with network theory sufficiently. He analyzes firms behavior on alliance building by carving out their different needs and capabilities (Gulati, 1995), which can be derived to the actors resources. An alliance is therefore established, when a social structure creates beneficial resources for the firm (Gulati, 1995).

When examining MREs, innovation theory can be adopted to encapsule emergent technologies, rounding up the theoretical framework. Connecting to examining networks, innovation ecosystems are capable of explaining networks in the context of innovation theory, consisting of actors, artifacts and institutions (Granstrand & Holgersson, 2020). These concepts connect broadly with network theory. What differs in innovation ecosystems are the ambitions for innovation through those relations. Innovation can either create or destroy value for actors (Granstrand & Holgersson, 2020), which creates a dimension of change in actor networks via resource allocation, dependencies and therefore power distribution. Hence, innovation of MREs in theory can change the innovation ecosystem or in broader terms inflicts with the other concepts of RDT and network theory.

At this point, it is visible that the framework resembles structures of actors, yet the governance perspective is missing. By investigating governing sustainable transitions, actor relations can be connected to governance. As transition researchers, Loorbach et al. (2017) explain that shifting power relations and role constellations are core mechanisms in any transition process. In these times of transition, governments inherit a role of management (Tukker & Butter, 2007). This would mean that governments can control resources, power distributions and transition pathways. In this theoretical framework, governments are understood as public actors which have resources allocated, and have an integrated role connected to other actors in the governance structure. Governing in the framework of RDT means that in sustainable transitions for MREs, governments may create resource dependencies which lead to political steering, for instance by legitimizing certain practices or working together with certain actors. Likewise, different actors possess different resources, which also create dependencies, relations, and collaborations. The character of each actor can be connoted to its specific resources. A company may have financial capabilities and test sites, whereas research institutes inherit resources in kind of information, which leads companies to engage with actors of different resource allocations. Investigating the network of MREs proposes the ability to understand the constellations between different public and private actors in the sector of MREs. This allows policy makers to take decisions based on understanding the framework of MREs incorporating actor relations and patterns, hence acknowledging private-public governance structures. Examining actor constellations allows to see through the opaqueness and complexity of a system with high technology acceleration, diminishing uncertainty and creating far sight. These policies are put forward by actors under the policy domain of renewable energy, leading to governance structures that inhibit the development of innovation practices. Therefore, the network includes a mix of public and private actors with different resources, which in

connection to MREs explain shifts of dependencies and values between actors in an emerging field driven by the energy innovation ecosystem close to sea basins.
In sum, the theoretical framework uses three main theoretical streams, being mostly resource dependence theory (RDT), network theory, and innovation theory. In line with this framework the sub questions can be answered, which enables to develop hypotheses, which can be tested in the analysis of the paper.

2.1 Innovation and involvement

The involvement of specific actors in MREs can at first be abstracted by examining which public and private actors are involved, based on possible resources at hand. This way, it can be understood how innovation influences certain resources, which could attract actors differently to join or leave the MRE movement, resulting in possible power shifts (Drezner, 2019). Here, the first sub question is theoretically examined:

SQ1: Which public and private actors are involved in the governance of MREs at the EU level?

Answering this question is done by using the established theoretical framework, which regards actors of a network as entities which can have different resources at their disposal, hence creating different actor characteristics. Therefore, actors that are different from another may not only differ in their organization but in the resources they have available. This allows actors of different characteristics to collaborate with one another, as the resources one actor typology may possess could create dependencies towards others. Understanding these typologies from on RDT perspective is needed for categorizing the actors in the analysis.

2.1.1. Actor resources

The first step of answering the sub question clarifies what certain resources are and how these may lead to classification between actors. This way, specific typologies can be connected to the resources an actor may possess, what that means for their power and how this could be governed in sustainable transitions with high innovation. Scholars of RDT have moved beyond the scope of defining resources as merely material goods or finance flows of corporations. Johnson (1995) puts forward the thought of symbolic resources, which deviate from purely materialist resources, which by exchange could produce solidarities (Johnson, 1995). In RDT, resources are used to describe dependencies and power asymmetries (Pfeffer 1987 in Hillman et al., 2009), which could entail that resources are relations driven and can be highly abstract. Considering RDT, if something can create dependencies, it can be regarded as a resource. Therefore, sorting resources is not fully possible as dependence creation is opaque. However, sorting some reoccurring resources broadly can grant easier examination when addressing the impact of innovation and power shifts.

Some resources are more palpable than others. In the case of MREs, one could differentiate between three main resource attributes, being materialist, abstract or somewhere in between. When it comes to material resources, there could be financial resources or human capital. This could be connected to energy firms and corporations which are producing MRE. Abstract resources could be information and knowledge. These are prevalent by examining actors in research centers or consultancies. In between these two spectrums are resources that could be described as abstract yet could also be connoted to materialist execution. An example here is legitimacy. This resource could be possessed by MRE projects, associations, and institutional bodies. If an actor has a lot of legitimacy, this entails that relations to this actor may lead to higher trust, enabling more cooperation possibilities. Likewise, associations could be created, which in the case of MREs form a more coherent body for official information exchange and legitimacy on the issue. It can be understood that with different resources at hand, different actors can be found.

2.1.2 The impact of innovation on resource demand in technology

Deconstructing actors by certain resources now allows to examine the impact of innovation on certain resources and its actor implications. This way, power shifts through innovation and possible opt in or opt out mechanisms can be understood, leading to understand involvement through the lens of RDT, innovation theory and network theory.

The impact of innovation on MRE governance networks can be understood from an International Relations perspective. According to Drezner (2019), with every innovation comes redistribution of power (Drezner, 2019). Therefore, actors that are in favor of the redistribution may opt in, whereas actors that are losing power may opt out of these innovative environments. Regarding energy innovation, this would entail that actors in the field of old energy systems like coal may be against innovations in renewables, as this could make them lose power in the process, changing market structures unfavorably (Mokyr, 1994). In International Relations it is prevalent, that the power dimension is important for actors' involvement in innovations as well as the relations they may create. Drezner (2019) differentiates four types of technology, dependent on the dominance of the public or private sector and its fixed costs. He puts forward prestige tech, public tech, strategic tech and general-purpose tech. In his view, the more technology moves towards the general purpose type (low fixed costs and private sector dominance), the more likely it is for this technology to diffuse (Drezner, 2019). For now, MREs may be niche research with high costs (prestige tech), yet it can be assumed that MREs are moving in a direction of general purpose, which entices new actors to join the field. These thoughts of actors are rather broad and do not make distinctions between them, as in the case of Drezner (2019), most of the actors connect to the private sector, which independently advances their technologies. By combining the overall thought of power shifts and innovation, RDT can be introduced to explain more in detail, how certain actors are influenced by upcoming innovation because of different resources at hand. A research organization for instance, has most of their capacities in information resources. With innovation, more uncertainties about MREs could pose a higher demand for research and therefore information resources by companies, projects, or consultancies. Because of that, a value shift in information demand could create higher dependencies for research institutes, leveraging more power actors that possess a high amount of information resources. This causal chain can explain innovation impacts for different actors in the field of emergent technologies. Different resources can be influenced by innovation, for instance the demand for higher legitimacy. This would entail that any actor that wants to establish legitimate causes would want to connect to certain institutional bodies that provide this resource, creating dependence and power shifts in the progress of establishing emergent technologies.

2.1.3 Governing innovation and actor involvement

For institutional bodies which could entail governments or organizations that fulfill a regulating structure, the regulation of innovation and MREs is significant for transitional governance. From the RDT viewpoint, governments would be able to create and shape environments which enable certain push and pulls for resources. A general example would be taxation, where a government could influence the produced resources by companies. Subsidies or funding for research associations could create more informational resources on the issue, which increases the value of such resource. In the definition of the theoretical framework, governance plays a significant role by influencing certain environments in their innovation resource demands. The potential of MREs already enables governments which can make use of this energy to acknowledge its prevalence. Ambitions of governments for putting MREs forward show possibilities of financing the emergent innovation, leading to a welcoming environment for such actors. These involved actors can be illustrated in a system, creating relations between them, and acknowledging the mix between public and private actors as such. A system that encompasses this mix of actors is understood here as the governance structure of MREs.

2.1.4 Opt in mechanisms with higher innovation

Innovations in technologies shake up the constellations of actors and their power distributions (Drezner, 2019). Emergent innovations can entice actors to join in the field of technology, allowing them to profit from this power shift. There could be different ambitions to join or leave the field of innovation, which are elaborated on in the following, calling them opt in or opt out mechanisms with higher innovation. Describing these processes as mechanisms makes them reactive and connects them to the innovation environment. Therefore, innovative acceleration can trigger causal chains in the theoretical framework that lead actors to join the field or makes them leave the environment. It is relevant to examine these mechanisms for analyzing and understanding a system of actor involvement. Understanding why actors may join or leave the field can be useful in deriving the first hypothesis. It needs to be carved out that as the resource allocation between actors is different, therefore their motivation to join the field of MREs can also differ. Using the explanatory possibilities of RDT, an actor may only opt in the field, when the current innovative force allows this actor to increase its resources, hence its power. Similarly, it can be argued for different motivations of actors. An energy company which has the main ambition to increase material resources like production values would be enticed to join an innovative movement only if that allows it to accumulate more of its core resource. Research institutes, founded on mostly informational resources may have easier possibilities to join innovative forces of MREs, because their research can more directly enrich their core resource. These motivations of resources and their capabilities in gaining value through innovation need to be kept in mind when examining the following mechanisms, which apply differently to each of the actors and their core resources.

The first opt in mechanism regards survivability aspects of actors. Global issues like climate change can execute pressure on actors to adapt to environments that focus on sustainability. This means that actors may adapt to new technologies if there is too much pressure building up in keeping old ones (Drezner, 2019). The narrative of struggle can be argued for in renewable energies like MREs. As fossil energies are one of the biggest issues tackled by governments in their decarbonization efforts, the pressure of survivability leads energy stakeholders to adapt to innovative energy solutions. One example for this mechanism has occurred in Germany, where actors from the coal and nuclear sector reconfigured themselves to adapting to offshore wind renewables due to changes in the Renewable Energy Resources Act (Baker et al., 2021). Therefore, one of the general mechanisms could be carved out as a struggle of survivability for actors in the field, especially when the surroundings adapt to emerging renewable technologies. RDT would encapsule this issue as a struggle of keeping relevant core resources for each actor, which leads to different motivations in moving forward with MREs, dependent on core resources.

The second mechanism can be interpreted as contextual fit. Some technologies which are dominant right now have been invented way earlier, however the historical context was not fitting, or society was not ready for such an innovation. Not only society needs to be ready for accepting innovative technologies. There also needs to be economic incentives for investing in an invention, as well as legal foundations. Therefore, legal and political decision-making render possibilities of enabling or disabling certain innovations (Pelkmans & Renda, 2014). This leads to the interpretation of Schumpeter's thoughts on innovation, which pass the stage of invention and need to be contextualized according to the developments of a system (Schumpeter, 1942 in Drezner, 2019). For some actors, competition can also be regarded not as a struggle but as a chance for adaptation. By pushing for new innovations in renewable energies, it entices engagement of new actors (Zohar et al., 2022). This creates first understandings that the context is also reliant on the actors already in the field. Therefore, the context is created by and reinforced through emergent actors. With continuous efforts for decarbonization by the EU, an arena is created that welcomes actors innovating in renewable energy efforts. It is present, that the relevance of the network leads to understanding innovative mechanisms. In combination with RDT, transitional governance can be understood as a guideline in the network itself, incentivizing relevant actors to opt in the field if it grants them the possibility of accumulating their core resources. Especially in the field of MREs, Bento et al. (2021) present determinants which lead firms to enter the market. They find that firms may enter the field of MREs due to market demands and the needs of the system, being technology performance and actor improvement. Also, their findings suggest higher opt in mechanisms when sectoral interactions are variety-led rather than relatedness-led, recognizing the diversity of a system (Bento et al., 2021). This mostly is tailored to firms, whereas governments could have a different set of motivations to join the field.

Especially when uncertainty resides in the emergent technology, it may incentive institutional bodies to regulate certain developments. For MREs, this could be clashes with ocean governance, energy governance or ecological aspects. The protective approach could therefore make governments join the network of involved actors to produce regulations that guarantee sustainability. Alongside the aspirations for protection are ambitions of blue growth, which motivates governments to ensure growth with ocean sustainability in mind. Navigating through these two diverging goals can be understood with RDT and network theory, which renders governments as actors of a system, applying governance that may lead to resource accumulation for many different actors of the field. This means that governments may opt in if the core resource of a government can be used to enhance overall MRE development in the system, enhancing research efforts for sustainability measures as well as corporations' development in emergent MRE solutions. This form of network governance can lead governments to opt in and set a trend toward opportune network developments. Conversely, firms can profit from the provided governance, as it ensures its legitimacy and creates an arena for a governed development of sustainable innovations. Hence, governments as regulators can be seen as protectors against an uncertain environment, where likewise the environment can be protected from the organization (Dill, 1981).

2.1.5 Opt out mechanisms with higher innovation

As seen in the opt in mechanisms for actors, it can be argued that actors accumulating higher innovation capabilities and a promising core resources are in favor of joining the arena of innovation. On the other hand, there could be possible disadvantages for actors to join innovative forces. These will mostly be argued by two mechanisms.

At first, the status quo is significant. If actors are reliant on their assets of the status quo, innovation and a change of power distribution could render them as losers of such redistribution (Drezner, 2019), forcing them to opt out. For RDT, this means that actors joining in MREs could also lose their resources, making them more dependent on other actors of the network. This means that losers in matters of the emergent innovation may actively not engage with the new technology, as they would lose some sort of asset (Mokyr, 1994). Concerning MREs, actors in the coal industry may not have the capabilities and incentives to opt in innovative schemes of renewable energies.

The second mechanism renders a more economic approach. For many actors exploring a new field, it may not be financially worth it to invest in a new technology. This fits with the contextual approach, as innovation is always coupled with governmental support and legal enablers (Pelkmans & Renda, 2014). If the reallocation of resources in the course of innovation depicts losers in this progress and it is not even worth to aim for survivability (Drezner, 2019), it could go as far as that actors of the field may create barriers for innovation to keep the status quo and their power (Mokyr, 1994; Neukirch, 2019).

Various interconnections of actors in times of innovation lead to the first hypothesis to be derived, which examines innovation and actor involvement in the case of MREs. With accelerated innovation of MREs, other actors of the energy field see the importance to join this trend, struggling to stay relevant in the field (Drezner, 2019). This could be because of political regulation, as well as legislative acts and funding (Pelkmans & Renda, 2014). Accelerated innovation then creates contextual pathways for actors to join the field.

Opt out mechanisms for actors play a role with accelerated innovation of MREs as well. Especially regarding energy actors in the status quo, entailing mostly coal and oil, power transition towards renewables could render them uncapable of adapting to new technologies. Contextualizing the issue, accelerated innovation in renewables including MREs, leads to political decision-making in favor of this technology, legal pathways, and financial support. Old energy actors may not fit in this context anymore and are therefore rather opting out of this technology, change their strategy or create barriers. Due to the trend of renewables and its demand for innovation, it can be estimated that more actors opt in and see this development as a chance in the redistribution of power in energy transitions. Therefore, the first hypothesis can be created:

H1: The higher the innovation status of MREs, the higher the number of public and private actors in the field.

2.2 Relations of actors in the energy network

In the next step, the relations of actors of the energy network are theoretically analyzed. In doing so systematically, the second sub question is answered in the following:

SQ2: How does the structure of the actors involved in the governance of MREs look like?

Examining the structure of MREs considers the same theoretical framework of RDT, network theory and innovation theory. Specific relational aspects are explained with the proposed theory, being mostly differences in fragmentation and coherence. Dependency and power derive from resources of actors; hence collaboration demands understanding on what actors may gain when setting dependencies to one another. The importance of governments in this is acknowledged, which can set certain incentives for dependencies. In times of accelerated innovation, innovation ecosystems could be created, which can generate positive values (Pushpananthan & Elmquist, 2022). Classic RDT focuses on one organization in a contextual environment, influenced by uncertainty (Hillman et al., 2009). For network theory this describes an introverted picture, accumulating social capital for one organization in the network with the goal to diminish uncertainties within the environment (Carpenter et al., 2012). In MREs, high technology acceleration may create a setting, which creates more uncertainties and more intangible capital, which could lead to higher dependencies between actors. Further investigating on the power structures and emerging fields of dependencies between organizations lead to investigation of concepts like fragmentation and coherence. Both factors are highly prevalent in energy governance network and MREs. The following paragraphs explain the concepts of coherence and fragmentation using the established model of the theoretical framework. This way, the structural relation between actors can be analyzed, answering the second sub question.

2.2.1 Fragmentation and coherence in the theoretical framework

The diversity of energy systems in Europe renders a challenge for assessing a continental trend. Because of scattered and differentiated national approaches to energy provision in Europe, energy governance is generally quite fractured (Eicke & Petri, 2020). Geographical ties are connected to the capability of exploiting certain energies dependent on the geophysical conditions of the country. EU member states may favor different energy mixes to create a resilient system in line with their own capabilities. Different private energy stakeholders try to have a meaningful impact on the energy provision of a country. Because of different geopolitical dependencies, political ideologies, and the influence of private stakeholders, top-down governing of energy infrastructure regulations is difficult. Many scholars ask the question of "Who governs energy?" (Apolonia et al., 2021; Florini & Sovacool, 2009; Guerra, 2018; Wilson, 2018) and why fragmentation in energy governance could be an issue (Apolonia et al., 2021; Eicke & Petri, 2020; Leal-Arcas & Filis, 2013). Understanding actors in the field of energy governance is examined by Sovacool and Florini (2012). In their work, they collect these actors by investigating different bodies that are involved in managing energy issues. This broad examination creates a diverse picture of all kinds of organizations involved in the process. Even though it is promising that there are so many different actors, scholars witness a fractured governance landscape (Wilson, 2018, p. 52). The consequences of fractured governance structures lead to difficulties in implementing long lasting goals or finding sufficient fit for regulatory measures (Apolonia et al., 2021, p. 14).

The theoretical framework grants assessment points for explaining fragmentation and coherence. For RDT, fragmentation can be explained under the premise that actors may behave reactive to the environment they are put in (Nienhüser, 2008). In general, RDT suggests that actors want to reduce their dependence to one another, hence seeking to accumulate most resources by themselves (Hillman et al., 2009). Explaining fragmentation through the lens of the theoretical framework, means for RDT theory that dependencies diverted. This can be achieved by actors that are less dependent on resources from other actors in the network. In relation to energy, this means that organizations have most of the needed resources and agency by themselves. Therefore, exchange and dependencies are getting less significant. In the case of MREs and innovation, this picture may change slightly. As new technology uncertainty arises, the importance of resources and their availability may change, which could create new dependencies, for example in founding research associations to accumulate information resources. The impact of innovation and its changes of resources can therefore explain both fragmentation and coherence. From the perspective of RDT, the structure of the involved actors varies according to the demanded resources, which again produces changes in innovation acceleration. These causalities connect with Drezner (2019), who emphasizes on power shifts through innovation and their relation towards actors.

The opaque landscape of energy governance resembles a challenge for the EU, as consensus driven decision making on EU level needs to encompass a significant leeway in goals that should not allow laissez faire actions. Instances of political fragmentation in energy governance is seen as a problem by multiple scholars (Apolonia et al., 2021; Eicke & Petri, 2020; Florini & Sovacool, 2009; Guerra, 2018; Leal-Arcas & Filis, 2013; Wilson, 2018). Political management, understanding energy governance structures and the impact of MREs depicts an urgency for getting actors together and understanding actor networks in MREs. Locating governments in the field of maritime energy networks can create possibilities of shaping the basis of resource dependencies. Regulating a fractured governance system which is changing through accelerated innovation, as it is the case for MREs, grants possibilities for governments to steer developments in such a way, that specific demanded resources lead to more actor dependencies, which could make the system more coherent, which could make other regulatory processes like sustainability measures easier to govern.

2.2.2 Barriers and enablers of relations between energy actors

In order to understand the structure of MREs it is necessary to focus on the different kinds of relations between energy actors, for instance by examining cooperation and what barriers could occur, leading to destabilizing or stabilizing transitional change (Neukirch 2019). Comparable to destabilizing and stabilizing factors, Apolonia et al. (2021) describe the different relations as barriers and enablers. Lange et al. (2018) see this issue in the MRE context. They depict a policy integration that includes all actors and therefore reduces barriers (Lange et al., 2018).

When creating new relations between actors the first factor is to enable a specific relation. This can be understood as a foundation on future relations. Most prevalent enablers in relations are twofold, being policy improvements and financial support (Apolonia et al., 2021). They present relevant conditions for enabling innovative technologies (Pelkmans & Renda, 2014). Positive relations are built on the basis of political decision making and its financial support which can lead to greater cooperation in the field, instancing in creating favorable environments for aspiring organizations to reside in. Apolonia et al., (2021) are mostly critical about the progress in MREs, however they see future improvement when adapting towards technology advancements, for instance by refining policies to the specific technology. They argue that until now decision making and financial support is rather targeting renewable energies in totality and not marine energies in particular (Apolonia et al., 2021). More tailored approaches to moving forward in MREs can be understood as enablers for innovation practices and positive relations between actors (Lange, Page, et al., 2018). Another enabler for relations is information exchange. Relations can be fostered if information is made available for more actors that can create research networks. These science-based actor networks may exchange information for instance to policy makers, enabling them to interpret generalized findings in a policy context (Zeigermann, 2021). This two-step approach allows science network knowledge to spill over to other sectors, which grants more possibilities of change, enabling cooperation between science organizations. Information exchange can enable relations towards citizens, as knowledge provision could reduce upcoming skepticism and uncertainty about the topic (Goffetti et al., 2018).

On the other hand, barriers between relations can also occur, which mostly resemble a lack of specific regulations and uncertainty (Apolonia et al., 2021). As a result, collaboration efforts could be dampened as it is unclear if engaging in the issue is worth it, which creates the fear of "betting on the wrong horse" (Neukirch, 2019). In this nexus of uncertainty, innovation can replenish trust in the energy, attract investments, as well as grant insights on more specific policy support mechanisms, at last creating more positive relations between actors in the field. This could make the structure of the network develop to be more coherent rather than fragmented. This way, the second hypothesis can be carved out:

H2: With higher acceleration of MRE technologies, relations between different actors in the field are reinforced.

2.3 Patterns in transformative processes of maritime renewable energies

Looking at the actors and structures in theory, the last step clears up examination of patterns and developments of network structures. For network development theory, it is important to point out certain possible overarching patterns between multiple actors, answering the third sub question:

SQ3: What are the patterns between different actor characters that are visible in the actor network?

The last theoretical dimension shows how certain patterns in actor networks may lead to an increase in power and interdependence of actors, transforming and developing the whole system. Examining these "relations of relations" creates an understanding of overarching patterns which allows to identify the impact of accelerated innovation of MREs on the governance structure. It is examined theoretically whether certain patterns could lead to more positive or negative developments in the network.

2.3.1 Heterogenous and homogenous patterns in energy networks

Gawel & Strunz (2019) represent an example for patterns in energy on this theory from a fiscal federalism perspective. They see a balance between homogeneity and heterogeneity in energy structures, dependent on the needs of decision making (Gawel & Strunz, 2019). This shows that in theory the advancement of MRE technology could go in two ways, either leading to more heterogenous actor patterns due to the character of the technology itself or to higher coordinated needs, which would entail cooperation and homogenous decision making (Gawel & Strunz, 2019). Interpreting homogenous and heterogenous patterns form the theoretical framework allows to complete the examination by including perspectives on power and development, allowing valuable insights in possible network developments.

It is rather typical to interpret positive developments with acceleration of innovation. This goes along with theories previously presented when examining opt in mechanisms and positive relation building (Apolonia et al., 2021; Asplund et al., 2021; Drezner, 2019; Granstrand & Holgersson, 2020). With accelerated innovation more actors join the field (see Chapter 2.1.4) and then create meaningful relations to one another by exchanging information or other enabling conditions (see Chapter 2.2.1). This forms a welcoming environment for a vivid technological development, which leads to a higher output of innovation. This could be done either in groups that are different from each other (heterogenous patterns) or clusters of similar actors (homogenous patterns), dependent on characteristics and resources. The patterns create a collective value which offers more power for the actors involved. Network governance could therefore take aim to create positive synergies in pattern building, which could lead to favorable outcomes for decision making.

Defining heterogenous and homogenous patterns is done here through the perspective of the theoretical framework. RDT postulates that each actor may possess different kinds of resources, defining its character according to the resource allocation. Dependencies are then created, if one actor is dependent on another actors resource, which leads them to establish an interorganizational relation (Gulati, 1995). A heterogenous pattern therefore describes the part of a network that consists of multiple different actor characters dependent on one another. This diversity allows them to generate collective value, as the needed resources are supplied by different actors, diminishing uncertainty. On the other hand, homogenous patterns imply the dependency on actors with similar character in part of the network. This could be beneficial for similar firms to channel their interests and bundle their resources to entice further innovation practices.

Both patterns are rather mixed a network yet can provide examination foundations for positive and negative developments in the network. As far as heterogenous patterns are concerned, positive development through the diversity of available resources can produce power, as cooperation in the part of the network with this pattern acknowledges each of the needed resources to diminish uncertainty. Power asymmetries can therefore be regarded differently, dependent on the development of the network and what resource is in demand. Homogenous patterns can also have positive developments, as bundled similar resources can also be considered powerful when innovation is established through the resource. This would be the case for research organizations or firms that can bundle their knowledge.

Certain patterns may create negative developments. This can be understood by examining the previous theory on opt in mechanisms and negative relations. Mirrored to positive developments, higher innovation could also make actors opt out (see Chapter 2.1.2). This may hinder the creation of relations to one another (see Chapter 2.2.1), leading to an unforeseeable governance structure. Hence, diminishing developments could make moving forward in MREs difficult. Heterogenous patterns in the network may gain their strengths through their diversity. On the contrary, this could also lead to a negative development, if the diversity of interest is too high and therefore does not align with long term goals of all the actors involved in this part of the network. This could lead to fragmentation and less dependency, minimizing the power output of the network group. Homogenous patterns can have negative implications as well. This may be the case when the dependency on other resources of the whole network is inflated because the homogeneity creates a two high demand for the resource. This could lead to reduced efficiency, power asymmetries and an unbalance of the system. Under the aspects of the given theoretical framework, network governance needs to be executed in a way that keeps a balance for the actors, orchestrating power dimensions for each actor characteristic and their resources. This way governments in Europe could strive for a balanced and fruitful exploitation of both network patterns. Even though MREs resemble a small scale of renewables to this date, innovation can already create patterns that may lead to power shifts and a transformation of governance structures. Considering the EU's ambitions in renewable energies, it can be argued that these innovations lead to more positive developments in the field of renewables, deriving the third hypothesis:

H3: With technological advancements of MREs over time, patterns between the actor relations create positive developments.

3. Analytical Approach

The complexity of actors in the maritime energy sector offers various ways of examining the influence of MRE innovation on different actors in the governance structure. Especially when examining changes over time, relations, and patterns, singular actors need to be contextualized to create a comparable body. The analytical approach is aligned with network development theory as put forward by Carpenter et al. (2012). In this approach, the main attention is put on analyzing the network itself, examining possible influences on the network. In the case of MREs, this influence is innovation acceleration. Testing the different hypotheses therefore connects with an analysis of different networks regarding their actors, relations, and patterns. In this analysis, actor networks consist of a web of dots (nodes) and connection points (edges), which can show interconnections to these nodes, almost comparable to the brain, with different neurons being connected to one another. This image can be retraced when examining actors with different relations. When this concept is transferred to political science, actors and their relations to other significant entities can be entitled as a governance network. In such a network, emphasis is put on intersectoral cooperation and partnership (Ramia et al., 2018). Different visualization techniques reveal finding not only interesting relations between actors of MREs, but also discovering missing links and patterns. Therefore a sufficient analysis of such socio-technical regime needs to encompass actors, institutions as well as technology advancements (Neukirch, 2019). Especially when examining transitions in energy, governance networks resemble a good comparable inventory in monitoring changes of the network. An example would be the study of Matschoss et al. (2020), where they decipher energy transitions in Finland, highlighting different areas of activity.

From the approach of network development research, Carpenter et al. (2012) derive three most likely biases, being endogeneity, structural autocorrelation and sample selection bias. When it comes to endogeneity, it needs to be emphasized that only the data from the materials is used to visualize a network, which does not include every actor of the field. To avoid omission, every actor is collected without a specific threshold, regardless of the size or importance of the actors. Regarding structural autocorrelation, each actor relation was analyzed manually, reducing correlations that could have occurred via automatization. Only in the visualization process, software was used, which allows the reduction of misleading structural autocorrelation, in this case relation analysis. Lastly, sample selection bias is regarded. This is a problem for network scholars, because a network can only be shown by incorporating relational actors, hence discarding isolated actors that do not have any connection to others (Carpenter et al., 2012).

The used sample of the Tethys database (see below) allows for any actor to be protocolled who has reported on the issue. It is the norm that more than one actor is working on a report, which usually creates at least micro networks between two actors. Isolated actors are only regarded in the first step by collecting all actors of the field, testing the H1. Moving toward creating networks, the cases of isolated actors have been omitted. The use of data and the case selection is elaborated further in the following.

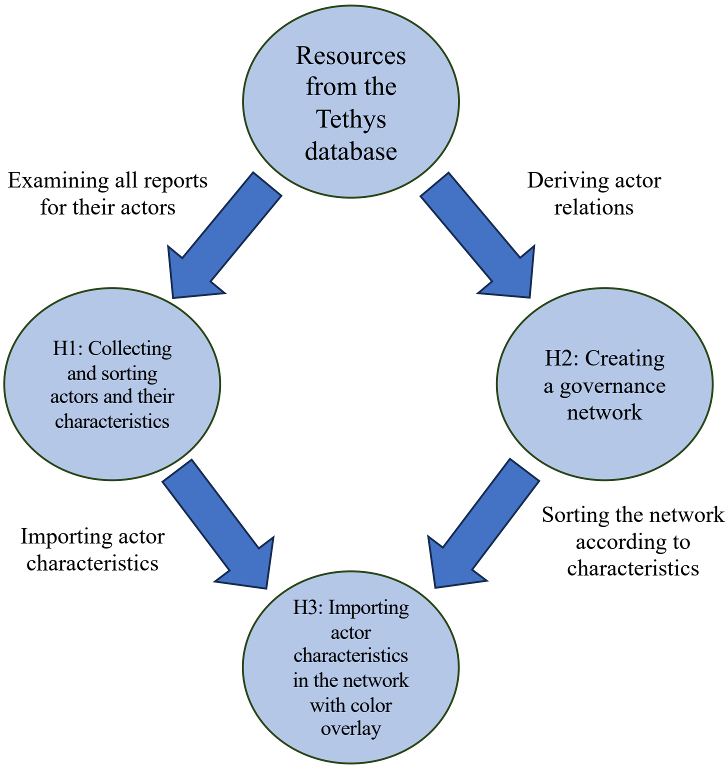
3.1 Sample/ Materials

Focusing to the core point, the analysis examines change of a network by examining two time periods. Comparing two time periods is a manageable way of examining change. Two different time periods were chosen, being 2013-2017 and 2018-2022. Examining time periods opposed to specific shocks in emergent technologies makes sense, as there is no exponential innovation given the structure of innovative processes. Especially when examining MREs, the innovation process appears rather linear, progressing through technology readiness levels (TRLs) over time. Collecting data over longer time periods therefore allows assessment which also takes accelerated innovation into account. With innovation as the driving force to be examined, 2018-2022 is a period of more accelerated innovation in MREs than 2013-2017. According to the Stragetic Energy Technology (SET) Plan of the EU, in 2018 a Temporary Working Group (TWG) for Ocean Energy set up its first Implementation Plan (Joint Research Centre, 2022). Big strategies like the EU Strategy on Offshore Renewable Energy were published in 2020, hence depicting a period which puts ocean energy in focus (Joint Research Centre, 2022). Earlier progress reports of the SET Plan, especially before 2018 were not that concrete concerning MREs. In the SET progress report from 2017, the potential of ocean energy is embraced, however does not consider specific plans on moving forward. Even though the potential is acknowledged, overall future driven goals were put on the private sector, without mentioning general future ambitions (Joint Research Centre, 2017). Another good qualitative reason for picking the relevant periods is the creation of the Marine Energy Alliance in North-West Europe (Last time assessed: 10.07.2023). Their main ambition is to move forward in marine technology, increasing TRLs in MREs respectively. As the project started in 2018 and was completed in 2022, it embeds the second time frame perfectly. A distinction between periods can therefore be made, which cuts a decade of innovation in the middle, setting two periods with different acceleration characteristics from the side of the EU, one being not as far on innovative processes in MREs (2013-2017), whereas the other period is already influenced by future ambitions for innovative advancement (2018-2022).

Data to compare both periods of development are derived from the Tethys database being the biggest report database on the issue (last time accessed: 04.07.2023). This database is especially useful because it allows to filter it using multiple parameters provided. Filters are set to reports and human activities. The filter on reports is straight forward and narrows down the material to the desired documents. Filtering "human activities" preselects reports which encompass only reports connected with certain projects or activities of MRE development, mostly excluding sustainability reports or impact assessments for specific animals. This way it can be assured that the collected actors are involved in the innovation process of MREs. Analyzing the database, it is only possible to find out constellations, as reports only allow to interpret those as relations. In this way, the network is presenting constellations, which can be interpreted as relations based on the previously established theoretical framework. By examining the actors for each period, it is possible to categorize them and put them into geographical context. These materials build a dataset which allows to encompass the complexity of each period.

3.2 Operationalization: Using the data to create actor networks

Indicating what material is used, the following graph presents the material and which operationalization is used for assessment:



Graph 1: Operational Framework

Testing the first hypothesis, a collection of actors displays the number of entities in the field, entitled to each period as well as occurrence in reports. These are private actors, like companies in the field, specific projects, or consultancies. On the other hand, there are public actors, which are collected by examining research institutes, institutional bodies, and associations. Emphasize is put on understanding the increase of actors in the field by comparing time periods, being 2013-2017 and 2018-2022. Derived from the reports in each period, the list of actors cannot be complete but resembles a snapshot of involved actors in each period. As innovation moves forward, it is expected to find a higher number of companies, research associations, and alliances as well as an increase in the number of executed projects. It is analyzed whether the hypothesis holds true by comparing the two periods regarding the emergence of new actors in the field. The hypothesis can be kept, when there is a significant emergence of new actors in the time frame of 2018-2022 compared with 2013-2017.

In the second part of the analysis, the second hypothesis is tested, which advances in not only examining the actors, but also the relations between them. This way, a thorough analysis between actor constellations from 2013-2017 and 2018-2022 is made. These constellations are examined by filtering the reporting actors and co-actors collected previously. By creating two networks for each period, it can be understood how the actors are connected in a system of reports. Operationalizing data for testing the H2 interconnects the actors and demands more complex technological methods. Excel is used to create an adjacency matrix dependent on the interconnections to be created. The actors previously collected are connected to one another by examining which actors wrote reports together. The generated matrix is then transformed and imported to Gephi, a program used to create networks out of the produced data. The abstract data can be visualized in a sufficient manner by using specific mechanisms, coloring, and size differentiation of the network nodes. Through the course of H2, two different networks for each time frame are created, dependent of the adjacency matrix screening various connections between co-reporting actors. These nodes (actors) will relate to no direction. For the H3, visualization techniques in Gephi are again used to show patterns, by coloring and sorting the different networks according to the categorizations derived for the inventory of actors. In addition, geographical connections are presented by examining the actors on a map.

4. Results: Private Actors

The following data is derived from reports provided by the Tethys database (last time accessed: 04.07.2023). This table presents the relevant actors in each period, starting with the private actors followed up by the public sector. Private actors in the field are either companies, projects, or consulting. Their appearance in the table is directly connected to the periods examined.

Private Actors	2013-2017	2018-2022
Companies	Aquamarine Power Ltd	Aquatera Ltd
	Aquatera Ltd	AW Energy
	Atlantis Resources	CorPower Ocean
	Bluepower NV	ELSA Energy
	DemoWind	GEPS Techno
	DP Energy Ltd.	Granitor Group
	Engie	HMK Automation Group Ltd
	Marine Current Turbines	Marine Renewables Industry Association (MRIA)
	Minesto	Minesto
	Natural Power	Mojo Maritime
	Oceanflow Energy Limited	Natural Environment Research Council (NERC)
	OpenHydro	Nova Innovation
	Quercus	Ørsted
	ScottishPower Renewables	RT SYS
	SSE Renewables	Svenska Kullagerfabriken SKF
	Statoil (Equinor)	The Crown Estate
	The Crown Estate	Wello
	Tidal Lagoon Power	
	Tocardo Tidal Energy Ltd	
	Vattenfall	
Projects	EcoWatt 2050	Biscay Marine Energy Platform (BiMEP)
	FaBTest	Morlais Tidal Array
	Iroise Marine Park	Orkney Marine Environment Project (OMEP)
	Morlais Tidal Array	Powerkite
	MUSES Project	Wave Dragon (Denmark)
	RiCORE project	Wave Energy in Southern Europe (WESE)
	Smartbay Ireland	Waveroller
	Tropos	
Consulting	Anatec	ECORYS
	E-CUBE Strategy Consultants	ERM (Marine Space)
	ECORYS	Finance for Impact
	Ente Vasco de la Energîa (EVE)	GoBe Consulting
	Eunomia Consulting	Hidromod
	Forewind	ICES Working Group on Marine Renewable Energy (WGMRE)
	Hidromod	IDOM
	Marine Coordination Group	Marine Scotland Science
	Marine Energy Programme Board (UK)	MarineSpace Ltd
	Marine Scotland Science	ORE Catapult
	MarineSpace Ltd	Pescares Italia
	NEF Consulting	Royal Haskoning
	ORE Catapult	RSK Environment
	Regeneris Consulting Ltd	s.Pro Sustainable Projects
	Royal Haskoning	SMRV Consulting
	Sciencewise	THETIS EMR
	Sciencewise Expert Resource Center	WavEC Offshore Renewables
	SMRU Consulting	Wood PLC
	WavEC Offshore Renewables	Xodus Group
	Xodus Group	

Table 1: Private Actors from the report database. Source: Tethys Database

The table resembles a starting point of analysis as the first findings can be understood by having a closer look at the private actors in the field. It can be found, that over time not a lot more private actors were involved in writing reports on MREs. It must be considered that missing actors in the second time frame does not mean that these actors have opted out of being involved in MREs. But it means that over the course of years no new reports were written by the company on that issue. This can still indicate some assessment on the activity of the private actors in each period.

Companies are rather ambivalent and the reoccurrence of the same companies in both periods boils down to three: Aquatera Ltd, Minesto, and The Crown Estate. These three companies can therefore be regarded as core private actor companies contributing to MREs over time. The other companies are not represented in both periods, which shows a lot of shifting in the actors of the field. It needs to be considered that in early technology developments like MREs, the overall density of reports is not that high: One company may only release a report in a few years after the successful completion of a project. Therefore, it is good to see diversified pictures of companies, as this shows a lot of different contributions to innovative MRE technologies. On the other hand, there is a decline in companies being listed in MRE reports, which is significant, given the few instances of companies involved in such projects. This leads to falsifying the H1, as it would suggest that with innovative acceleration in the period of 2018-2022 a lot more companies as private actors would join the field, which cannot be seen.

This leads to the next category of private actors, which is MRE projects. These projects present different actors in each period, except for the Morlais Tidal Array. This is understandable, as in MRE technology, innovative acceleration is driven by different projects over shorter amounts of time, usually maxing out around 3 years. It can be understood that innovation is staying on a high pace, presenting similar amounts of projects, with various targets. A remarkable increase in projects cannot be found, which explains a linearity of innovation in the technology. For the H1, the number of projects is rather linear and a significant increase in projects cannot be confirmed on. It needs to be acknowledged that the development in quality of projects as well as dimension in growth is not regarded here. The number of reported projects does not concur with the estimation of actor increase for the H1.

The last group regards private actors in consulting. They resemble a specific role in writing reports as they are creating a bridge between research and company communication. Especially in writing reports, this group of private actors can be a good indicator for examining activity in the filed over time. This group of actors has the most commonalities in each time period including mostly the same actors like ECORYS, Hidromod, Marine Scotland Science, Marine

Space Ltd., ORE Catapult, Royal Haskoning, WavEC and the Xodus Group. Even though this group is the biggest of the private actors, the continuity of similar actors as well as the slight decrease in 2018-2022 leads to discarding the H1, as not only a few new actors have joined the field.

The findings of a first list of private actors in the field of MREs leads to questionable outcomes. There is not a big increase in private actors in the period 2018-2022 which is what the H1 would have suggested. High change rate of actors in both time periods leads to the interpretation that MRE technology is still in its beginning stage which suggests that multiple innovative approaches are scattered. An exemption is the consultancy groups, which have more actors in common over the periods. This could also be the case because of the adaptation possibilities of big consulting groups, which makes them stay involved even in times of change. To test the first hypotheses in total, the following paragraphs examine the public actors of the field.

4.1 Public Actors

In the public sector, the examined actors are very differently involved in MREs. This is also because of the geographical nature of some actors. To find only relevant public actors in the field, it is examined, which public institutions are writing reports on the issue. Mainly, there can be three categories of actors found, being research institutes, institutional bodies, and associations. For each period the public actors can be examined in the table below.

Public Actors	2013-2017	2018-2022
Research Institutes	Aachen University	Acadia University (Canada)
	ABP Marine Environmental Research Ltd (ABPmer)	AZTI-Tecnalia
	Aquatic and Terrestrial Ecology (ATECO)	Bangor University
	AZTI-Tecnalia	Blue Economy Cooperative Research Centre (CRC)
	Bangor University	Centrale Nantes
	Cardiff University	Centro Tecnológico Naval y del Mar
	Centre for Environment Fisheries and Aquaculture Science (CEFAS)	Commonwealth Scientific and Industrial Research Organisation (CSIRO)
	Centre for Marine and Coastal Studies Ltd (CMACS)	Ecole Central de Nantes (ECN)
	E.ON Energy Research Center	Ecologic Institute
	Ecole Central Nantes	Engineering and Physical Sciences Research Council
	Engineering and Physical Sciences Research Council (EPSRC)	European Marine Energy Centre (EMEC)
	European Marine Energy Centre (EMEC)	Habile
	Fraser of Allander Institute	I.N.C.D.M Constanta
	Fraunhofer	National Ocean Technology Center (China)
	Glyndwr University	Norwegian Institute for Water Research
	Helmholtz-Zentrum Geesthacht; Zentrum für Material- und Küstenforschung	ORJIP Ocean Energy
	Institute for Future Energy Consumer Needs and Behavior (FCN)	Pacific Northwest National Laboratory (PNNL)
	Irish Marine Institute	Queen's University Belfast
	Joint Research Centre (JRC)	Scottish Association for Marine Science (SAMS)
	Marine Ecology and Management Section (MARECO)	Stellenbosch University (South Africa)
	Marine Energy in Far Peripheral Island Communities (MERiFIC)	University College Cork
	Martin Luther University Halle-Wittenberg	University of Edinburgh
	MSH Medical School Hamburg	University of Liverpool
	Natural Environment Research Council (NERC)	University of Montenegro
	Operational Directorate Natural Environment (OD Nature)	University of Strathclyde
	ORJIP Ocean Energy	University of Tokyo
	Plymouth Marine Laboratory	University Plymouth
	RAVE: Research at Alpha Ventus	Uppsala University (Sweden)
	Robert Gordon University Aberdeen	Working Group on Marine Benthal and Renewable Energy Developments (WGMBRED)
	Royal Belgian Institute of Natural Sciences (RBINS)	
	Swansea University	
	University Bremen/MARUM	
	University College Cork	
	University of Edinburgh	
	University of Exeter	
	University of South Wales	
	University of Strathclyde	
	Uppsala University	
	WOZEP project team	
Insitutional Bodies	Department of Communications, Energy and Natural Resources (Ireland)	European Commission
	Dutch Ministry of Economic Affairs	European Environmental Agency (EEA)
	Enablers Task Force (Irish Government)	Finnish Environment Institute, Marine Research Centre SYKE
	European Commission	International Council for the Exploration of the Sea (ICES)
	Falmouth Harbour Commissioners	International Energy Agency (IEA)
	German Federal Maritime and Hydrographic Agency (BSH)	International Renewable Energy Agency (IRENA)
	International Council for the Exploration of the Sea (ICES)	Marine Energy Wales
	International Energy Agency (IEA)	Natural Resources Wales
	Marine Management Organisation (MMO)	Orkney Islands Council
	Natural England	Scottish Government
	Natural Resources Wales	Scottish Natural Heritage (NatureScot)
	Natural Scotland	United Nations (UN)
	Northern Ireland Environment Agency (NIEA)	United Nations Educational, Scientific and Cultural Organization (UNESCO)
	Norwegian Ministry of Climate and Environment	Welsh Government
	Ocean Energy Forum	
	Orkney Island Council	
	Scottish Government	
	Scottish Natural Heritage (NatureScot)	
	Sustainable Energy Authority of Ireland (SEAI)	
	Swedish Agency for Marine and Water Management (SwAM)	
	Swedish Environmental Protection Agency	
	The Highland Council	
	The Marine Institute (Ireland)	
	UK Department of Energy and Climate Change (DECC)	
	Welsh Government	
	WWF	
Associations	Islay Energy Trust	Annex IV Member Nations
	Marine Alliance for Science and Technology Scotland (MASTS)	Asociación Centro Tecnológico Naval y del Mar (CTN)
	Marine Renewables Industry Association (MRIA)	Marine Alliance for Science and Technology Scotland (MASTS)
	Megavind	Ocean Energy Europe (OEE)
	Ocean Energy Systems (OES)	Ocean Energy Systems (OES)
	OECD	RenewableUK
	RenewableUK	Scottish Renewables
	The Nautical Institute	Supergen Offshore Renewable Energy Hub
	United Nations - World Conservation Monitoring Centre (UNEP-WCMC)	The European Technology and Innovation Platform for Ocean Energy (ETIP Ocean)
	Vindval	
	World Ocean Council (WOC)	

Table 2: Private Actors from the report database. Source: Tethys Database

Comparing the two periods, the overall number of public actors declines significantly. By examining research institutes, universities resemble the biggest part of actors. Core actors in research institutes for MREs is the European Marine Energy Centre (EMEC) and its research project ORJIP Ocean Energy, as well as AZTI-Tecnalia. With more innovative acceleration, the H1 would suggest that more research institutes would join in. By examining and comparing the list of 2013-2017 to 2018-2022 a decline of a third can be seen. This is clearly against the assumptions put forward by the H1, which would stipulate a rise in public actors, especially when it comes to research institutes, as they put forward innovation.

Comparing the institutional bodies, the trend is even more severe, which cuts public institutional actors in half when examining 2018-2022. Mostly prevalent are international bodies like the European Commission or the United Nations (UN). Governments from Great Britain are dominant in being involved with reports and the progress of MREs. This is clearly linked to the geographical possibilities given to Great Britain, exploiting such energies, and establishing research sites like the EMEC. Environmental bodies like the European Environmental Agency (EEA) and the International Environmental Agency (IEA) create a perspective of environmental regulation to the mix. Overall, the number of reports backed up by these institutional bodies has declined in 2018-2022, which is not in line with the assumption of the H1.

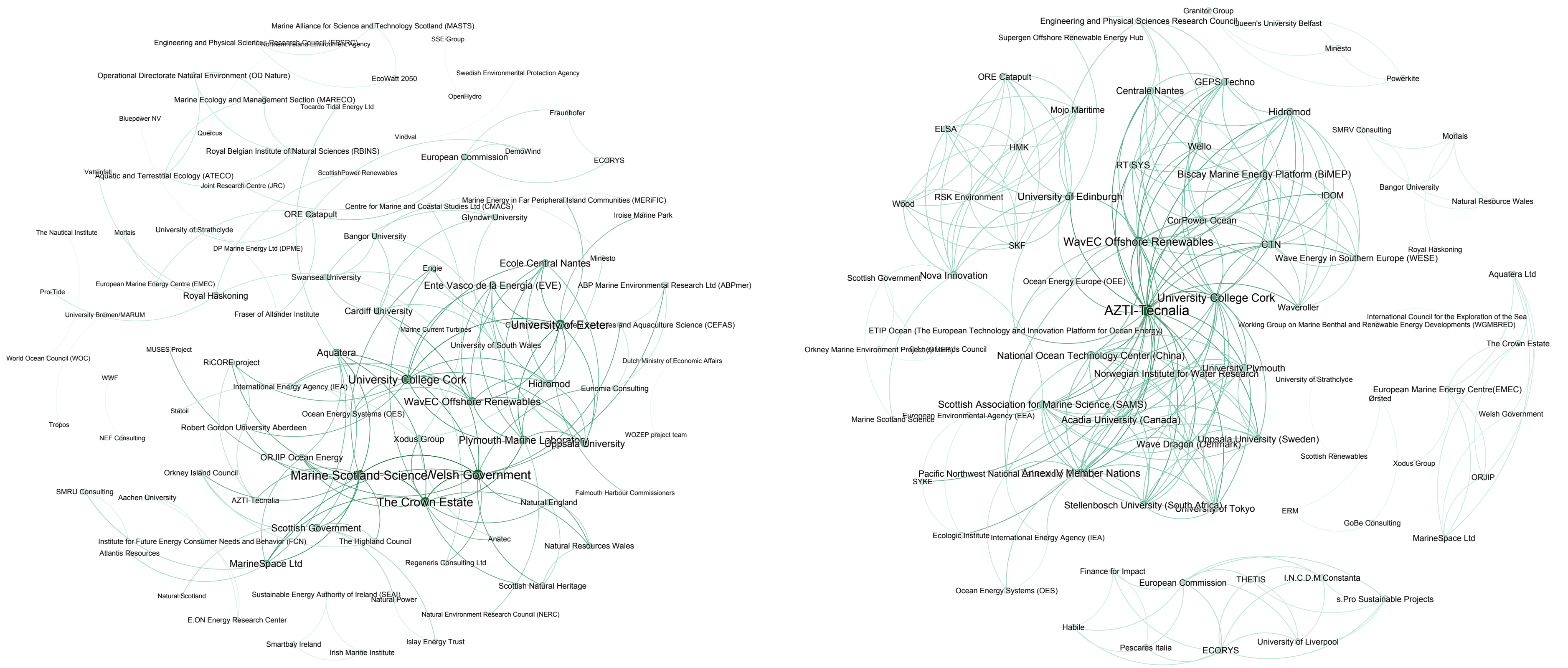
When it comes to associations of public actors, the quality of associations seems to have increased in the period 2018-2022. Annex IV Member Nations, Ocean Energy Europe, as well as the European Technology and Innovation Platform for Ocean Energy (ETIP Ocean) resemble alliances that are structurally more connected and put forward efforts of innovation internationally and in the EU. In 2013-2017 smaller associations like Megavind (DK) or Vindval (SE) were keener on connecting knowledge in a nation. With the efforts of the European Commission, platforms like ETIP Ocean gather knowledge more broadly in Europe. Regarding associations, the H1 could be considered, as the number of associations is not decreasing that much. The interconnectedness between such actors is touched upon further by interpreting the findings for the H2.

4.1.1 Testing the H1

The findings for sorting and understanding public and private actors in the field of MREs are not as expected. By comparing the number of actors in 2013-2017 and 2018-2022, there were less actors in the more recent period for every single category. The expected outcome of more actors over time can therefore not be held true, which discards the H1. Specifically, the overall number of actors which occur in reports in the Tethys database decline, which cannot be located to a single category of actors. The decline is especially high in the public actor categories like research institutes and institutional bodies. The latter can be qualitatively examined with a higher orientation towards international and European institutions in 2018-2022. Overall, less reports were released on the platform which also explains the decline of actors. In the period from 2013-2017 114 reports with 130 actors were counted, whereas from 2018-2022 it were only 53 with 98 actors. This shows a lacking number of actors in the second period presenting a decrease in actors by 35,41%. Revisiting the H1: "The higher the innovation status of MREs, the higher is the number of public and private actors in the field.", the hypothesis cannot be kept in the case of the Tethys database. With a higher innovation status in MREs which resembles the period of 2018-2022, the number of public and private actors in the field does not increase. On the contrary, the number ceases to decline. This could be the case, because of longer lasting goals which are reported more sparsely or with the loss of emergent actors in this technology, as the barriers for implementation and experimentation are quite high. The volatile state of MREs can be seen here, as a lot of actors are changing in the field, which makes examining them over time difficult.

4.2 Report Relations

Examining actors and their relation to one another can be a difficult task. Gathering information that goes beyond finding alliances of actors which could be half-heartedly agreed upon may not encapsule the essence of cooperation. Therefore, the findings of this part seek to find relations between actors by examining the link through reports. This way, it can be assured that the actors really were working together on a coherent piece and are joining their intellectual and resource driven forces. Understanding these relations clearly depicts a "real world" picture which is opaque yet grants dense information. Especially when examining meaningful exchange, written reports or reports that were written for some actor clearly show a connection. This has been done by analyzing not only each actor but each report thoroughly, investigating who wrote reports together. In doing so, a system could be created, which allows a step back of individual reports to see a full picture of the MRE actor system. The transition of the system from 2013-2017 to 2018-2022 is embarked on in the following.



Graph 2: Report Relations 2013-2017 (left), 2018-2022 (right)

Source: Tethys Database

All the actors previously connected are now put together in one system. What can be seen here is that the above collected actors from the first hypothesis now create a system that is connected, dependent on the number of actors connected through reports. On the one hand there may be a report written by WWF and NEF Consulting that has no other connection points. On the other hand, some actors have written multiple reports together, which allows more connections and more of a web. In general, the network of actors in the period 2013-2017 is rather scattered. Some network is visible in the “Great Britain Web”, where actors like Marine Scotland Science, Welsh Government, The Crown Estate, or the University College Cork create important connection points. In the upper part of the system, the influence of the European Commission can be found, connecting to important actors like ORE Catapult or Royal Haskoning, which feedback into the “Great Britain Web”. However, it is visible that the overall connection of actors is not that far developed yet, and relations are not that reinforced. In numbers this means that 95 nodes are visible, which connect to 155 edges, a score that shows a rather loose connection between actors in the system. Even though there are many actors in the field, it is evident that they are not that well connected to one another, which means that there were not a lot of big collaborative projects that led to writing a report with multiple actors involved.

Moving to the period of 2018-2022, there can be examined significant change. It is visible that the system has moved way closer together and collaboration is enforced. In numbers, a slight decrease of actors is visible (in line with discarding the H1), being 79 nodes. However, the connection points are way higher, counting 271 edges, being 74.84 % higher compared to the edges of the period 2013-2017. It is visible that the system now has less loose ends and more collaborative clusters, which are examined in the following.

It is evident that the core system of the period 2018-2022 has increased in density, emphasizing on actors like AZTI-Tecnalia, WavEC Offshore Renewables and a mix of universities and consulting groups. There are a lot of reports that connect the same actors, which reinforces the network. However, over time, the more actors are involved in each of the reports, the denser the network becomes. This can be seen in the core cluster built around AZTI-Tecnalia. Other interesting report clusters render the ambitions of the EU, which connect ambitions of the European Commission connected to advisory bodies like ECORYS. It can be argued that because of the nature of reports not the whole system of collaboration can be displayed. For instance, ETIP Ocean, a program developed by the EU, does not connect directly through the examined reports with the European Commission, even though these actors are working together. Therefore, written reports grant a good picture that is connected to real world ties, but not to broader collaboration efforts. In the case of the period 2018-2022, the European

Commission as an actor is not as connected as to the rest of the system and builds a cluster in the lower part of the network. Connecting these clusters can work via specific actors that can connect two clusters. This can be seen by the University of Edinburgh, which connects to the core system, yet also to the outer rim, bringing together more actors. These connecting points of clusters seem to enhance the comprehension of a more coherent system in 2018-2022, leading to reinforced structures of the system.

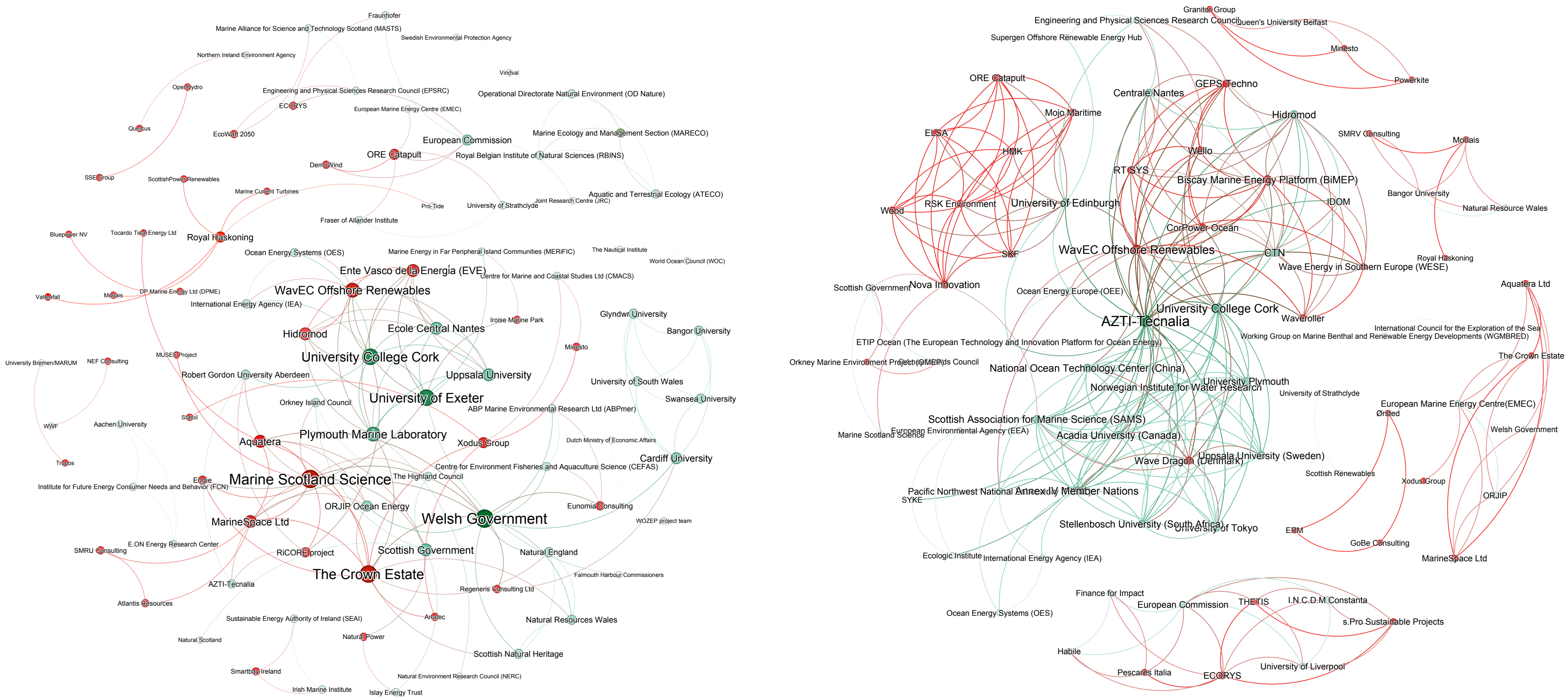
4.2.1 Testing the H2

Examining the H2, "With higher acceleration of MRE technologies, relations between different actors in the field are reinforced.", the hypothesis is supported, as in the landscape of writing reports together, more relations can be found in the period of accelerated innovation (2018-2022). In the first period, a loose web can be seen, which presents a fractured system of reports, being mostly small clusters and dyadic connection points. The 2018-2022 timeframe visually and empirically shows more connection points, bigger clusters of actors and intermediaries, which connect actors to one another. In numbers, an increase of 74.84 % edges in 2018-2022 compared to 2013-2017 can be recorded, which renders a significant increase in density and reinforcement of the network.

4.3 Interdisciplinary network with attributional diversification

For now, two main findings can be acknowledged. With higher innovation acceleration, it does not need to be the case that more actors are joining the field, at least not when examining reports (H1). On the contrary, it can be shown, that actors are reinforcing their relations with one another, hence creating more relations, and writing more reports together (H2). This presents that innovation must have some influence on actors and their behavior. What is left undone is to understand how characteristics of each actor may lead to different patterns. It will be carved out, whether there are more promising patterns in the 2018–2022 period compared to the 2013-2017 period. Two assessment points entitle characteristics and geographical allocation.

For this final analytical step, there is no need to create another new network, but to examine each period multidisciplinary. The setup for the research pivots in not only comparing the two networks, but rather to find an explanation for transformative patterns moving from 2013-2017 towards 2018-2022. This way, meaningful patterns can be carved out and already show some effect. In so doing, prospects can be created that ensure predictions moving forward from 2018-2022 to the future. Then, ultimately, the final hypothesis can be tested. The findings connect the categorization efforts of the H1 and the network mechanics of the H2 to create insight in specific patterns of the system. The nodes are colored differently dependent on their character. This way, different patterns in the combination of actor characteristics can be examined. As a first step, the difference in public (Green) and private actors (Red) is presented, which allows the assessment of actor patterns.



Graph 3: Public and Private Actors 2013-2017 (left), 2018-2022 (right)

Source: Tethys Database

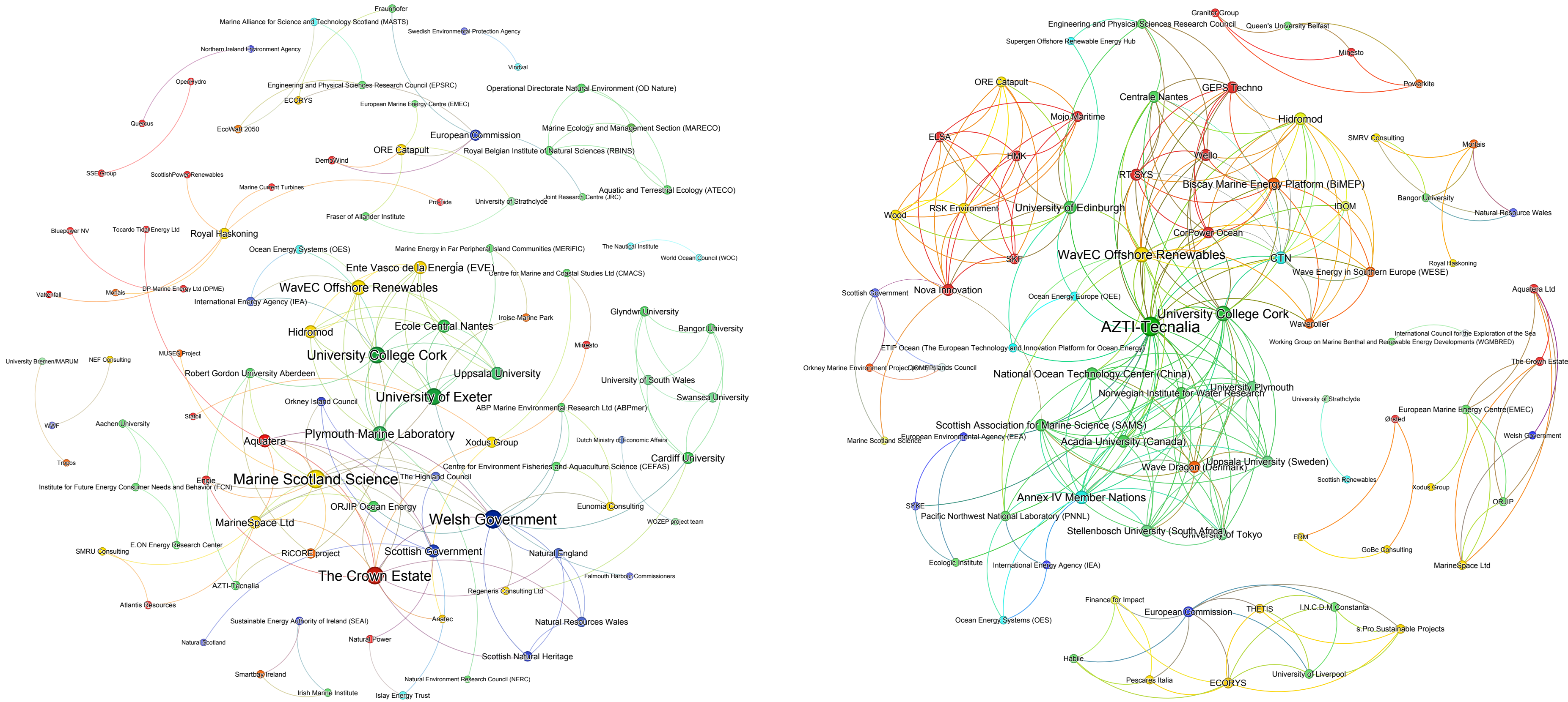
First examination of the period 2013-2017 creates a mixed appearance of public and private actors. Different clusters resemble different interaction needs between the public and the private sector. If a company proceeds in a project and writes a report about it, oftentimes authorities or research centers are involved as well. Only in rare cases there is an accumulation of merely private or public sectors. Higher numbers of connection points between public actors can be seen in university networks, research centers and governments, for example by examining the relations of the University of Exeter or the University College Cork. However, these systems are never fully exclusive for either private or public actors. An example for private actors would be Marine Scotland Science and their connection points, which are mostly private. Especially by examining smaller clusters which occurred due to smaller reports one can see private actors more dominantly. This could be the case as smaller projects demand more involvement of private actors. When these projects grow and innovation accelerates, more public actors could get involved as well. In general, the overall actor segmentation of public and private actors in 2013-2017 is ambiguous. No clear separation of public and private actors can be examined, which makes sense, as in most of the reports both actor groups are involved.

The network in the period 2018-2022 presents clearer segmentation and grants insights in clusters that are either dominated by public or private actors. There are two kinds of clusters to be examined, one where the dominance of private actors is influenced by a few public ones, and one where the dominance of public actors is accompanied by some private actors, for instance projects. The dominance of private actors can be seen for instance in the top left of the actor clusters. Here, actors like ORE Catapult, Nova Innovation or RSK Environment dominate the field, whereas one public actor is the outlier, being the University of Edinburgh, which then also connects to other clusters. On the other hand, there is the big public actor network of the Annex IV Member Nations, which backs up private projects like Wave Dragon.

Two important insights can be documented in these instances. When it comes to mostly private clusters, the public actor connects other private clusters together, creating a coherent system. This can be seen for instance by AZTI-Tecnalia, University College Cork or University of Edinburgh. When it comes to mostly public actors, these systems are already connected quite well, and another private actor may enact only as a bonus. The importance of interconnecting actor systems therefore lies by the public actors. In mixed actor clusters, there are mostly a few private actors which are then backed up by public ones. This is visible by examining the lower cluster with the European Commission.

In comparison with the period 2013-2017, it is visible that in the period 2018-2022 clear clusters have formed that are either more connected towards private or public actors. Public actors seem

to be the driving force in connecting different clusters of the system with one another. Universities involved in different projects are an example here. Over time and with accelerated innovation it is visible that smaller systems with private actors now attract more actors in projects, as well as the influence of public research institutes. Where in the period 2013-2017 a lot of small actor clusters in private as well as public sectors were common, in periods of accelerated innovation (2018-2022) more public actors join forces with private ones, which leads to more coherence and mixed clusters. It can be argued that over the course of innovation, the public and private sector found to one another and gained value from each other. A dynamic of conversion leads to a system that is more interconnected and mixed in their actor attributes.
Understanding the patterns between public and private actors is a great help in understanding how actor relations are shaped by accelerated innovation. The next step not only encompasses public and private actor relations but assigns a color to each of the defined actor characteristics from testing the H1. This way, a more nuanced character of actor patterns can be examined, which distinguishes private and public actors further. These actor types have sub characteristics, which are colored in the following, where companies are red, projects orange, and consulting yellow. For public actors, research institutes are green, institutional bodies blue and associations cyan. By illuminating each characteristic, findings for each characteristic are presented in the following, which are then contextualized to understand the patterns between them in different times of accelerated innovation.



Graph 4: Actors with attributional diversification 2013-2017 (left), 2018-2022 (right)

Source: Tethys Database

What is visible in the time frame from 2013-2017 is that the field of different actors is very opaque. A lot of different actors intermingle with others, but no real bigger structure can be seen. Oftentimes, actors like Vattenfall and Royal Haskoning work together on a report, or companies like the SSE Group and OpenHydro create a relation, yet with no other connectors. Mostly, companies connect to consultancies and projects. Projects are rather rare and connect mostly to companies and universities. In the private sector, the most important actor seems to be consultancies. With their research focused traits, they share commonalities with research centers, which create the core of the mixed system of 2013-2017. Research centers like University of Exeter or University College Cork resemble an important asset in early innovation practices of MREs, which can be interpreted in the multiple ties that connect each other, rendering the core of the system. Institutional bodies as well as associations resemble a subordinated role due to the number of them and the lack of connections, mostly to research centers.

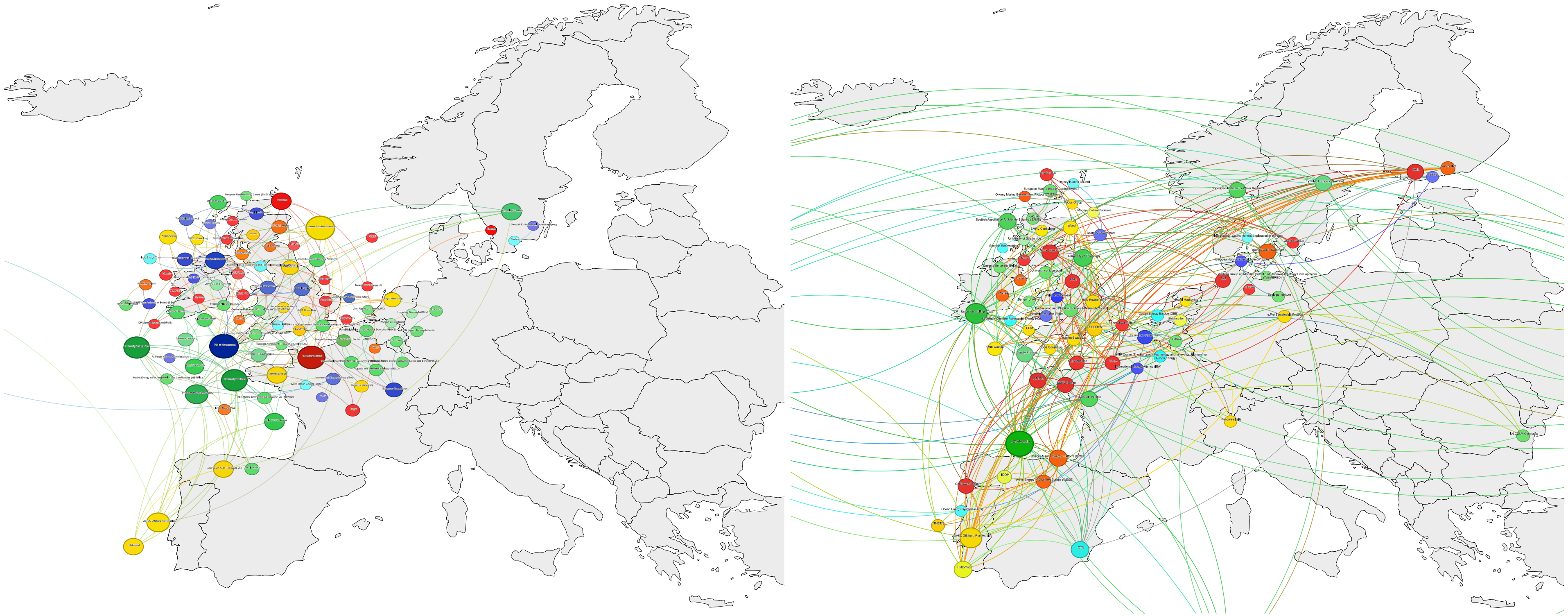
The time frame of 2018-2022 grants great insights about actors and their characteristics. Companies tend to connect more to one another, which can be seen in the upper left part of the system. There seem to be some bigger projects supported by multiple actors, for instance the Biscay Marine Energy Platform (BiMEP). Consultancies seem to be rather similar in importance, however it seems that they are more scattered in different projects, working together with different actors and research institutes. Especially WavEC and Hidromod seem to gain importance in that time frame. Similar effects of clustering can be seen when examining research institutes. Especially AZTI-Tecnalia is a big connecting point of multiple actors, creating a cluster of research institutes, incorporating private actors as well. This cluster can be seen as the core of the system. Even though quite small, in some clusters institutional bodies resemble at least one connection point. This can be seen in the case of the cluster connected to the European Commission. Similar observations apply to associations, whereas two associations gained importance, being the Annex IV Member Nations, as well as CTN.

Overall, with closer examination of different characteristics of public and private actors, it can be said that significant differences in the periods can be examined. Over time, two main developments can be understood, being approximation of the same characteristics or mixing different actor characteristics in one cluster. One the one hand, actors of the same character seem to connect more to one another. This could be explained with cooperation efforts with matching interests of companies under each other or research interests of universities. An example for this is visible in the green research clusters or in red company clusters. On the other hand, over time developments could also lead to a more colorful mix of different actors in one cluster. This way, different inputs of actors can be acknowledged in a report and create a multifaceted approach. This is visible in the enclosed clusters, which encapsule almost all different actor characteristics, for instance examining the European Commission cluster 2018-2022, or the Welsh Government pattern 2018-2022.

Both observations have positive and negative implications. In a cluster that is more focused on one characteristic, bigger systems can be created as they may reach out to competences of other actor characteristics, like research centers. This can be seen in the red cluster of 2018-2022, where mostly companies connect to the University of Edinburgh. Negative implications could be that the diversity of such a system may be difficult to establish when too many similar actors accumulate. For heterogenous patterns, diversity is already established, which makes multifaceted approaches easier. Negative implications could be that once the actors have covered all different characteristics, they are less likely to connect to more actors of the field and remain a small cluster. Both developments happen simultaneously, creating clusters of similar actors as well as mixed actor characteristics. Accelerated innovation can therefore lead to bi-lateral developments in fragmentation and coherence of actors with different characteristics. Whether both types of clusters lead to positive or negative development is not that obvious, as both clusters have its positive and negative implications. However, it can be argued, that due to the occurrence of both types of clusters in one system, resilient MRE networks can be created, as all demands for a coherent network are in scope. For mono characteristic clusters, the need to connect with actors of different character is prevalent, which connects the system more. For multi characteristic clusters, they already set up shop for significant interdisciplinary exchange, which puts forward innovation. With the existence of both cluster types, the network is on its way to creating homogenous patterns with each other into one coherent mixed system.

4.3.1 Geographical dynamic network allocation

The last findings present patterns in geographical allocation. Positive developments would postulate that in a period of accelerated innovation not only relations are reinforced (H2), but also positive patterns are created (H3). Seeing these networks from a typological perspective has been done in the last paragraph. By examining the geographical specifications, it can be checked how much influence the location of actors has on collaboration efforts. This way, the interconnectedness of Europe can be visually worked out.



Graph 5: Geographical mapping of MRE actors 2013-2017 (left), 2018-2022 (right)

Source: Tethys Database

Examining the first geographical map of actors in the period of 2013-2017, it is visible that most of them are originating in Great Britain and Ireland. Especially in Orkney, northern England, research projects and institutes settled, like Aquatera and the European Marine Energy Centre (EMEC). Picking this location finds a natural explanation, as the nature there creates perfect environments for testing sites. The favorable position of Great Britain leads to multiple research institutes investigating MREs, as well as the creation of companies and consulting. Local governments like the Welsh government as well as the Scottish government started being involved too, writing reports in collaboration with research institutes. Funding was even backed up by The Crown Estate. On the other side of the sea basin, Northern France was involved as well doing research, as well as the Netherlands and Belgium, Germany as well with one small project. Three outliers encapsule Spain, Portugal, and Sweden, where there may be not that many actors accumulated but still promising ones, like Hidromod (Portugal), AZTI-Tecnaila (Spain) or Uppsala University (Sweden). From a broader perspective, it can be argued, that settlement for MREs is connected to the possible exploitation of natural resources and closeness to Great Britain. By examining actor connections usually some traces lead back to Great Britain. Examining the visualization, spillovers to the mainland of Western Europe are created, which lead to an understanding of the relation between actors, countries, and the need for feasible resource exploitation to move forward in MREs. The period of 2013-2017 creates a geographical assessment that ensures a valuable starting point for examination.

Examining the geographical mapping in the period 2018-2022 of MRE actors shows way more connections between the actors. Especially towards institutions outside of Europe, more connections can be made. This is mostly due to reports of the Annex IV Member Nations, including actors from Tokyo, Canada, United States, South Africa, and China. Focusing on Europe, Great Britain still is the country with most actors involved and most of the connections. However, it is visible that the spillover continues along the European coastline with more countries now involved, being Denmark, Norway, Finland, Italy and Romania. It can be argued that with higher innovation acceleration more positive developments are created, as in a geographical realm, collaboration and quantity of countries involved has increased. From the prevalent countries involved with MREs, Spain and Portugal have mostly increased their output, actors like AZTI, WavEc Renewables, Hidromod turn out to be essential for the MRE system as it is today. For instance, WacEc Renewables works closely together with the global association Ocean Energy Systems (OES), which feeds back information to the whole system. As the biggest newcomer, Denmark strongly joins the scene with reports on its project of

Wavedragon and research institutions connected to it. Also, first reports of the European Environmental Agency are published, based in Denmark as well.

Comparing the two periods, a visible increase in countries involved and connections made is documented. Actor constellations now move more and more beyond Great Britain and spread over the coastline of Europe. Where in 2013-2017 local research institutes in Orkney started off MRE projects, mostly these institutes collaborated and only reached out to a few connecting countries sharing the same sea basin as France or sometimes Spain. With accelerated innovation of the field, developments in 2018-2022 lead to a positive outcome, where more countries are involved, more connections are made, and the significance of actors' impacts has moved beyond Great Britain.

4.3.2 Testing the H3

Actor patterns exceed the realm of investigating one area of effect solely. In times of accelerated innovation, all gears of a machine start spinning, some faster, some slower. What could be seen in these developments is not only how different energy governance actors work together, but also that they reinforce each other. In case of the examined instances, results of actor patterns are mostly positive and reinforcing. By comparing the developments of actors in times of accelerated innovation, 2013-2017 does not present clear distinctions between public and private actors. Examining the period 2018-2022, this picture is clearer, and clusters start to form. These first patterns can be interpreted in a way, that in times of accelerated innovation actors with similar characteristics (public or private) connect more with one another. This can be regarded as a positive development, as firmer structures are formed, which may enable better cooperation. In connection to the theoretical framework, this issues the positive development of homogenous patterns.

It is possible to sort actors even further by filtering them with the characteristics established in the first part of the findings. A clearer picture can be created that confirms the assessment of public and private actors: Actors with similar characteristics may cluster together. Additionally, within enclosed clusters, different characters of actors can be identified that may reinforce their strengths, which could enhance positive developments. In connection to the theoretical framework, this connects with heterogenous patterns. Put together, the two kinds of patterns can be carved out, one that with accelerated innovation connects more actors of the same type, and two, connects actors that have different types but are in a smaller sub system. Combined, these two effects lead to examining positive developments. For one, bigger clusters of the same actors lead to a demand of actors with different characteristics, which enables collaboration. Also, smaller actor systems with different attributes can be a good example of interdisciplinary collaboration, which are needed to put further development forward. The insights in those patterns grant the possibility to keep the H3.

As another check for collaboration, geographical assortments can be used to grasp the impact of innovation and positive developments even further. For that, the actors have been sorted according to their geographical location. In 2013-2017 mostly Great Britain was involved in writing reports about their proceedings on MREs, establishing connecting points mostly to adjacent sea basin countries, like France, Spain, The Netherlands, and Belgium. Therefore, mostly the western coastline of Europe was used in these beginning stages. In the period of 2018-2022, the collaborations and the area of effect have increased, leading to positive development, encapsuling more coastal countries, as well as more importance of actors outside Great Britain. In times of accelerated innovation, the geographical examination also suggests keeping the H3, as over time positive developments can be carved out that include more countries as well as rising the importance of already established ones.

5. Discussion on H1, H2, H3

This section takes inventory of the hypotheses tested and whether the findings can test these sufficiently. Each hypothesis is considered, which in the end can answer the research question: "How do newly emerging renewable maritime energy technologies shape the structure of energy governance networks in the EU?"

The transformation to maritime renewable energies (MREs) was examined by examining two periods which encapsule different accelerations of innovation. These periods are examined using the biggest database on MRE reports in the respective periods being 2013-2017 and 2018-2022. Examining the actors that were involved with the reports, it was possible to find out the actors of each period (testing H1), creating relations to one another (testing H2), and understanding patterns of characteristics of these actors (testing H3).

Energy governance networks can be examined narrowly by progressing through testing the different hypotheses. Due to the small sample of reports, this network is not all encompassing and does not try involving every actor involved. As a snapshot of reports, these actor systems can still present certain developments of actors in times of accelerated innovation. This can be helpful removing general trends from the analysis, as only written reports on the issue are embarked on. This creates an analysis of the "world out there", establishing accurate relations between actors as well as examining realistic developments of the issue. Testing the first hypothesis already presents the reality of assessment, as by collecting the actors of the field it is evident that in the period 2013-2017 more actors are prevalent than in 2018-2022, which debunks the H1. In times of accelerated innovation, it does not need to be the case that more actors are involved. It should always be kept in mind, that the examination of actors solely relied on the appearance of them in reports. Therefore, precisely it can be said that in 2013-2017, more reports were published on the database which included more actors. In comparison to 2018-2022, less reports on the database which also included less actors in that period. This could have reasons connected to the theory of opt out mechanisms of actors in a specific field, for instance keeping the status quo. The second hypotheses regards whether actor relations may be reinforced in times of innovation acceleration. With the help of a network on which actor wrote which report together, the density of the network is significantly higher in 2018-2022 in comparison to 2013-2017. In numbers, the number of edges in the network from 2018-2022 is 74.84 % higher compared to the edges of the period 2013-2017. Visually, reinforcing clusters are established. Seeing these changes in the periods leads to keeping the H2. Lastly, testing the H3 emphasizes more on patterns by comparing the two periods. This has been done in three ways, first characterizing public and private actors, then narrowing it down to characteristics set in the actor collection. Lastly, geographical ties were examined. The results suggest keeping the H3, as in times of accelerated change, positive developments have formed. For one, public and private actors have clustered together, joining forces to bring innovation forward. Each actor then was colored according to its characteristic, which led to finding out about two cluster types, one being mono clusters of one type, but in a bigger accumulation, the other being multi character clusters, which are not that big but encapsule multiple characteristics. These two pattern types lead to a combined ideal type of a network, which embarks on homogenous and heterogenous patterns. Combined, there are two positive developments being the thrive for collaboration by the homogenous patterns as well-established beneficiaries by heterogenous patterns, leading to positively testing the H3. Positive developments can also be located when examining the geographical allocation of actors in the different periods. Comparing the periods, extension of actors over the European coastline can be examined. This can be evaluated as positive development, because with the progress of accelerated innovation, more countries actively participate in writing reports therefore being involved in MREs. The shift from not only Great Britain but to other countries like Spain or Portugal suggests that positive developments lead to incorporation of actors of different countries with rising significance. The geographical as well as the typological examination of actors in the field of MREs lead to keeping the H3.

In this paper, the evaluation of transformation to maritime energies is mostly connected to times of accelerated innovation in the MRE sector. Transformation depicts the change from a period of low innovation (2013-2017) towards a period of higher innovation (2018-2022). The structure of energy governance networks renders the system of actors in the field of MREs. Here, a governance network entitles a network that involves both private as well as public actors. In connection to the theoretical framework, the influence can be seen in three ways, being a higher number of actors in general (H1), stronger relations in between the actors (H2), and positively developing patterns (H3). According to the evaluated documents, it cannot be said that with the transformation to maritime energies, more actors join the field. There are a lot of reports on the issue, however it seems like the number of actors writing them has declined in innovative times, a development that is contrary to the theorized findings. In the period 2018-2022 however, the relations between actors which are measured in who wrote reports together, have increased significantly. Even though less reports were written by less actors in 2018-2022, more connections were established with more actors collaborating with one another. Lastly, with the transformation to MREs, more positive developments can be acknowledged. For one, more patterns are created, which are either from a homogenous or heterogenous typological nature. Combined, they create positive developments in times of MRE transformation (2018-2022). Geographically, more actors in different countries are involved which gain more significance in the network.

6. Conclusion and outlook

Multiple scholars see fragmentation in energy governance (Apolonia et al., 2021; Eicke & Petri, 2020; Florini & Sovacool, 2009; Guerra, 2018; Leal-Arcas & Filis, 2013; Wilson, 2018). Questions like "Who governs energy" or "what impact does energy have on political bodies" are orbiting the discourse on energy governance. This research finds its way into the discourse with an impact analysis of marine renewable energies (MREs) on the actor network. Who are the actors of MREs, what connects them, what system do they create? When it comes to emerging transformative technologies, the thought of innovation is inherently connected to it. Thinking of countries and International Relations, impact of innovation on said actors embarks on theory of power distribution and shaking up the status quo (Drezner, 2019). Theoretical implications for resource dependency theory, network theory and innovation theory explain actor characteristics, how relations are formed through dependencies and what specific patterns could emerge. Connected to the theory, it should be acknowledged how a comparison in periods of change depicts a change of the network, which has been done in this paper. The periods present different acceleration points of innovation, one being 2013-2017 and 2018-2022, collecting MRE actors of the field. As material for data extraction, the Tethys database on MREs is used (Tethys database ;filters set to: human activities, reports, last time accessed: 04.07.2023). This enables an approach on all actors of the time frames that have written any sort of report on that issue. It has been analyzed that the number of actors has decreased, even in times of higher innovation. The relations between them, however, have fostered, which means that less actors seem to collaborate more on writing reports together. Collaboration could happen between different public and private actors, more specifically companies, consultancies, projects, research institutes, institutional bodies, and associations. Examining those by comparing them in different periods led to finding out positive developments in periods of accelerated innovation.

These findings leave us with an understanding of innovation, especially MREs that to some extend mirrors assumptions of the theoretical framework and its derived hypotheses. It is visible that accelerated innovation moves actors in the system together, balancing out the creation of diversity and joined forces with likeminded actors. Visualizing those insights in a network can create easy communication flows, that lead to clear analytical possibilities. As straight forward this analysis is, it embraces only the materials analyzed. Reports do not encapsule the whole picture of a system, therefore it needs to be understood that these are not all the actors of MREs. Yet still, this also makes the findings sufficient, as they show not more and not less the landscape actors derived from reports in each period. By arguing with the database of reports, subjective judgment on the involvement of actors is cut out. The time periods 2013-2017 and 2018-2022 show enough difference in TRL levels of projects and overall advancement and awareness of MREs. Earlier time frames show a technology that has been merely touched upon, which also shows why earlier timeframes do not depict enough significant change. However, further studies should emphasize on different periods to understand a chronological impact timeline. Beyond the difficulties of picking a time frame, the extent of analysis also depicts an issue, which in future research could be extended to other materials of actor relations, creating networks that encompass more actors, perhaps even in the whole energy governance system. Ideally, this way the impact of MREs on the whole system can be evaluated. The European Marine Observation and Data Network (EMODnet) provides information on every single project ever done in MREs in Europe. Working with this dataset could create encompassing findings, which would connect to a complete system. Findings may share similarities to the ones found is this smaller research, yet could be more generalized, as the full scope of MRE projects can be regarded. Two more variables could be examined, being funding of projects and legislative ties to examine developments more connected to governing. Funding could be a weighted component in the future research, where legislative ties enact as a directed system enhancement that includes more governmental bodies. An analysis like this could present more nuanced connections between actors. External shocks on a network like this need to be considered as well, especially when including more variables. As an example, for a shock like this, would be the Brexit. Especially by examining MRE development, Great Britain is a key figure here, with actors like the European Marine Energy Centre (EMEC) and multiple scientific organizations in both periods (see Chapter 4.3.2). The focus of this work are reports and collaboration in innovation, where external shocks like Brexit could not be regarded. When broadening out the research, these shocks need to be acknowledged and can enact as a great opportunity for future investigation.

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