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SYSTEM TRANSFORMATION FOR GROWTH AND SUSTAINABILITY: OCEAN ENERGY IN PORTUGAL

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1 INTRODUCTION

This report addresses *the role of systemic policies in the construction of an Ocean Energy System* - that is, a system that originates from the development and diffusion of renewable energies based on the ocean.

The choice of this case study can be justified by the fact that the development of an ocean energy system combines two central dimensions in the Systems Transformation Project. On the one hand, it is part of a process of low carbon transition, through the introduction of a new generation of renewable energy technologies that extend the variety and scope of clean energy production, thus contributing to the goal of achieving secure, clean and efficient energy supply. On the other hand, these new technologies can drive the creation of a new (sustainable) economic activity, which will also bring about the revitalization and transformation of existing sea-related industries (often traditional or declining), thus contributing to fulfil the goal of an ocean-based growth. It therefore offers an interesting case to examine how sustainability and structural change goals can be combined.

The ocean has the potential to become an important source of clean energy: according to existing estimates the ocean energy resource available globally exceeds our present and projected future energy needs. In the European Union the highest potential is in the Atlantic coast and Portugal is one of the countries where important resources have been identified. The concept of ocean energy used in this study is broad, encompassing all technologies aiming to exploit this resource, both those harnessing the power of the ocean (e.g. wave and tidal energies, as well as temperature differences and salinity gradient) and those located on the ocean (offshore wind: near shore or deep-waters). In the case of Portugal, the relevant technologies are wave energy conversion and deep-waters offshore wind conversion. Other technologies have very limited (or no) expression.

The strategic importance of the ocean is recognised in national and European policy documents that have put a growing emphasis on the development of an "ocean-based economy". The ability to use the ocean as a source of renewable energy is part of this strategic approach. It is namely pointed out that EU countries have achieved a leading position in this field and should endeavour to maintain it. Thus the field has been singled out for policy support, both at European level – where the "Blue Energy" is one of the pillars of the "Blue Growth Strategy" - and in several member countries and regions. This is namely the case of Portugal that has formulated a Strategy for the Sea and an Action Plan to implement it, of which ocean energy is also one central element.

Ocean energy is, in fact, a potentially important area of activity for Portugal that has good natural resources, particularly in what concerns wave energy[1], and a longstanding presence in the field. Portuguese actors have conducted an important activity in wave energy from the early 1990s, being among the pioneers in the development and experimental test of wave energy systems in Europe, and retaining a central position in international scientific and technological networks. Activity in the offshore wind took-off later, but Portuguese organisations are currently leading the development of one of the most advanced floating offshore wind prototypes. The long-lasting involvement of Portugal in the ocean energy field, led to the creation of an important community of actors engaged in the development of an

[1] The gross global wave energy resource along shore (annual average) has been estimated to be around 15 GW on continental Portugal and 6 GW on the Atlantic Islands. The global (worldwide) resource is estimated to be approximately 2TW, which was, at the date, in the range of the annual average of worldwide electricity consumption (WAVEC, 2004).

ocean energy industry, which includes scientists, companies and a variety of other economic and social actors, active at the national, international and also regional level.

However, there still is some way to go before ocean energy can fulfil its potential. Despite the high expectations ocean energy technologies have progressed slowly and are still relatively immature. Even if different technologies are at different stages of development, ranging from research to pre-commercial demonstration, important investments are still required before they reach the commercial stage, and there still is great uncertainty regarding the way the process will unfold. Recent European level debates on how to move forward have stressed the need of moving beyond the fragmented approach that has so far characterised the field and adopting a more integrated view, which acknowledges the need to build a system and addresses simultaneously the various problems that prevent that system from developing. Besides the technological problems that need to be solved and the high costs and uncertainty still involved (that also weaken the competitive position towards more mature renewable energy technologies), the construction of the new system will require the alignment and coordination of activities and actors that originate from a great variety of fields and industries, including technology intensive (such as ICT), established (e.g. metal construction) and traditional (some sea-related industries). This multifaceted nature of the emerging system increases its complexity, but its transformative potential lies, exactly, on the new connections it can induce and on the changes its development is expected to bring about in other systems.

It is therefore particularly important to understand how to accelerate the process of development and implementation of these technologies and, in particular, how to guarantee that such process takes place in a way that effectively contributes to the more systemic objective of transforming the ocean-based economy. Given the nature of aforementioned problems, the emerging system is heavily dependent on the guidance and the dedicated support offered by formal and informal institutions (e.g. political commitment, policy goals and vision, quality of regulatory framework, policy instruments, etc.) However, as evidence from renewable energy innovation journeys demonstrates, policies have not always been effective in inducing transformation at this level. Thus, it is necessary to rethink policy making and develop new policy perspectives on how to support the emergence of innovations with high potential for sustainable development.

Systemic policies are receiving increasing attention among innovation scholars and policy makers, as an integrated and coherent set of tools explicitly designed to target the problems that emerge at the level of the innovation system as a whole (rather than focusing on the specific parts of that system) and that negatively influence the speed and direction of innovation process. These problems also referred to as 'structural systemic failures' are caused by processes firmly embedded in social structures, and, as a consequence, their resolution is bound to involve both innovative practices and structural transformation. The purpose of systemic policies is to steer these processes of change in the desired direction, given their capacity to create opportunities and conditions for system formation - that would not otherwise emerge spontaneously - and to accelerate innovation processes. In terms of design, systemic instruments can either take the form of programmes, or be smart compositions of individual tools that reinforce each other and are able to address systemic problems in an orchestrated way.

This report aims to analyse the role played by systemic policies to support the development of an ocean energy system in Portugal, focusing on the articulated application of four such policy instruments: roadmapping; pilot & demonstration; smart regulation, clustering. We propose that, in order to effectively understand how policies influence system innovation and transformation, it is necessary to analyse the *co-evolution* between policy making and the dynamics of the emerging system, with a view to detect how they impacted each other over time. The final goal is to understand how an attempt at supporting a process of system innovation and transformation driven by new complex technologies took place in a specific context (ocean energy in Portugal); which were the key policy decisions and the main problems faced in their implementation; and what can be learnt for similar processes and/or more generally for the formulation of systemic policies.

The report is structured in the following way. Section 2 briefly characterizes the main ocean energy challenges and points to their policy relevance. Section 3 discusses how the systemic policy instruments under study can respond to these challenges. In Section 4, we conduct a historical analysis of the attempt to develop of an ocean energy system in Portugal in the last two decades, focusing on the co-evolution of policy making and system dynamics, with a view to better understand the role of systemic policies and policy instruments in this process. Finally in Section 5 we sum up the findings and discuss lessons learned with respect to systemic policy contribution to system innovation and transformation: key processes underlying the formulation and (lack of) implementation of systemic policies; opportunities, challenges and critical points related to individual instruments application.

2 OCEAN ENERGY SYSTEM: CHALLENGES AND POLICY RELEVANCE

2.1 A SYSTEMIC ISSUE

The development and diffusion of ocean energy technologies and the formation of an ocean energy industry requires a systemic approach. First of all, it involves the construction of a new system. The emerging system results both from the development of new competences, activities and business models associated with the new technologies, and from the transformations these can induce in existing systems. These transformations can involve the upgrading of existing competences and resources, the development of new capabilities that add value to existing activities, the emergence of new sources of competitiveness, and entail the engagement of new and existing actors with the system under construction. Thus, the development and diffusion of ocean energy technologies goes much beyond solving technological problems, requiring the articulation and alignment between technological, economic, social and institutional processes. A systemic perspective is required in order to fully understand and adequately address the needs of the emerging system.

A systemic approach is even more pertinent given the particular characteristics of the system being built and the goals that are to be achieved with its development. Ocean energies are at the intersection of two distinct areas – energy and ocean. Not only each one of these areas has its particular dynamics, which may impact upon the development of the new system, but they are very diverse and have been (so far) largely unrelated. Thus the need to link between and integrate them can raise particular challenges, which can only be addressed with a systemic approach. Moreover, since ocean energies are expected to contribute to the revitalization of some sea-related industries (while also benefiting from their competences), coordination with broader strategies and policies being implemented as part of the development of an Sea Economy are indispensable.

2.2 SYSTEM FEATURES, CHALLENGES AND POLICY RELEVANCE

Considering the nature and stage of development of the technologies and the current configuration of the emerging system, the main challenges to system development can be found along four dimensions:

a. The development and diffusion of ocean energy technologies is an element of an (ongoing) sustainability transition process;
b. The new system is driven by a set of immature and complex technologies;
c. The construction of an ocean energy system requires crossing boundaries between heterogeneous fields and industries;
d. The introduction of ocean energies requires addressing new questions in what concerns the (shared) use of the sea

These challenges call for system transformation and raise a number of policy relevant questions in terms of 'why' and 'how' policy needs to change to allow this transformation.

a. Ocean energies are *part of an ongoing sustainability transition process*.
The development and diffusion of ocean energy technologies is part of the process of transition to a sustainable energy system, being confronted with the obstacles usually associated with such transition processes. More specifically ocean energy is one element of a major transformation in the energy (electricity) production system: the development, introduction and diffusion of renewable energy technologies (RET). This is an area where Portugal has considerably advanced, being currently among the countries with higher RET penetration. Even if there is still a long way to go for an effective energy transition to take place, the most basic aspects associated with energy production from RET are being addressed: important changes have already taken place in the structure and organization of the electricity production system, a regulatory framework was established and is being consolidated and a range of supportive policies is currently in place or is being (re)established. This permitted an effective market penetration of the most mature RET (onshore wind) and also created some conditions for the (uneven) development of less mature ones, including wave energy, where Portugal engaged in some pioneer activities. These processes contributed to the creation of a structure of actors, networks and institutions that configure the embryo of a renewable energy system, encompassing both new entrants and some incumbents.

Recent developments – the economic crisis and the country bail-out - have slowed down this process. They led to changes in policy and some withdrawal of government support, in particular to technologies that were at more incipient stages, as was the case of wave energy. Even if there appears to be again a reversal of attitudes towards RET, this political instability had some damaging effects upon the progress of the ocean energy field.

From a policy perspective, it can be argued that there is a favourable environment for RET development and market diffusion, from which ocean energies can obviously benefit. But it is also a fact that ocean energies, because of their immaturity, *ended-up being somewhat marginal in the process of development of renewable energies and need to be more decisively incorporated in that process*. The ocean energies analysed here have a number of particularities that differentiate them from other RET (as will be discussed below), which will need to be taken in consideration by RET policies if they are to effectively contribute to a *wider sustainable energy transition process*. How this can be achieved leads to a greater policy challenge, which is to *understand the systemic role of the various renewable energy sources* (e.g. ocean, onshore wind, solar, hydro, geothermal, etc.) in the ongoing transition process, and framing their development accordingly. This requires a broader policy strategy that identifies potential complementarities between parts of the system and makes the needed connections, so as to facilitate an efficient and effective transition.

b. The construction of an ocean energy system is being *driven by a set of immature and complex technologies.*

Ocean energy technologies are still relatively immature. Even if the various technologies being developed are at different stages, none has yet reached the market. This means that system actors still need to solve a variety of scientific and technological problems to stabilize the technology, scale it up and improve performance/costs, in order to make it attractive to potential investors. In the case of ocean energies, the problems usually associated with this process are compound by the need for engaging in extremely expensive experimentation in stages still characterized by high technological and market uncertainty and regulatory indeterminacy. Actors also need to develop efforts to build a new institutional framework that support technology implementation and diffusion, particularly in these areas where the emerging technology raises new issues, not encompassed by the existing RET regulatory framework. In what concerns the commercialization of the new technologies, while demand side policies for RET are in place and can support the early stages of market introduction, in the long run ocean energy technologies will still need to engage in considerable efforts to reduce energy costs, in order to become competitive with other RETs. Finally, the two main ocean-related technologies being developed in Portugal (wave energy and floating offshore wind) are in different phases, having different requirements that need be taken into account to avoid crowding-out, while the synergies and the common problems they raise will benefit from being jointly addressed.

Ocean energy technologies are **complex technological systems** whose full development entails the performance of a variety of activities, requiring the establishment of an integrated value chain. This value chain combines core activities related with the development and optimization of the energy conversion system, with a range of complementary activities associated with the manufacturing, installation, operation and maintenance of a complete energy production system. A substantial part of these activities involves competences present in other sectors, in particular those related with operating at sea, thus requiring the engagement and alignment of actors from different areas. Since a fully operative system requires all these activities to be performed, the appropriate composition and organization of this chain needs to start being tested a relatively early stage, in real operation conditions. Moreover, in order to ultimately prove the viability of the technology and/or to further improve performance costs, a full scale system has to be demonstrated at sea during longs periods. This entails high investments and requires building or gaining access to costly infrastructures. The development and consolidation of the new value chain also entails the need to build new system-level institutions.

From a policy perspective, the uncertainty and complexity that characterize the development of ocean energy technologies raises a specific policy challenge: how can policies provide a more stable environment, that does not add another layer of uncertainty, and that reduces complexity in the coordination of different actors, competences, and activities across the value chain? Such stability and coordination in the external environment is of particular importance for developers and investors. In this context, can conditions of stability be made compatible with flexible experimentation and learning to support the development of immature technologies? This may also be essential to allow technological innovation and competition in the infant phase, while promoting the conditions for viable technologies to upgrade along the different development stages, improving efficiency, reducing costs and attracting investors and potential users, within a stable environment.

c. The development of an ocean energy system requires *crossing boundaries between heterogeneous fields and industries*

The new value chain being created involves combining areas with very diverse industrial structures, technological orientations, cultures and institutions. Complex technologies that combine competences and actors from diverse areas always raise governance problems. But this great heterogeneity, as well as the fact that a substantial part of the complementary activities involve competences from sea-related industries, that in Portugal are often traditional or declining, is likely to create greater difficulties in terms of actor mobilization and alignment. Moreover, the engagement with the new technologies may require actors from these sea-related industries to diversify into new areas, entailing investments in the acquisition of new resources and development of new skills. While these are exactly the processes that make ocean energies a potential driver of transformation of sea-related industries, the very nature of these industries (in terms of resource availability and competence base) makes the process more challenging.

From a policy perspective the development of ocean energies provides an interesting example to better understand how, in processes of transition, can policies contribute to facilitate synergies between the new technological sector that emerges from the innovations under development (e.g. the new ocean energies), and traditional sectors that appear to be under demise (e.g. shipbuilding). How can systemic policies support the maintenance of competences, skills, and infrastructure from less technology intensive and less risk oriented industries that, nonetheless, may be important across the value chain of the emerging ocean energy system, and link them with the new ones, bringing together diverse actors? Is a broader view of systemic policies for ocean energy, which encompasses very diverse activities, industries and policy-areas related to the ocean economy, essential to support the development of the emerging system and the transition process?

d. Ocean energies require *addressing new questions in what concerns the use of the sea*

The introduction of ocean energy entails the *production of energy at sea***,** i.e. the occupation of a public space to develop a new economic activity. It also entails the sharing of that space with other economic and also non-economic activities (e.g. transport, fishing aquaculture, leisure and nature conservation), which may lead to acceptance problems, particularly in local communities. Thus, the development of this new economic activity in the ocean space raises a number of legal, environmental and societal issues that will require coordination between different stakeholders.

From a policy perspective this case highlights how transition processes may require addressing a set of new regulatory questions and, eventually, a new regulatory framework that goes beyond the existing framing of traditional activities. Namely, the development of ocean energies requires contemplating issues related with maritime spatial planning and defining a specific regulatory framework (e.g. consenting and licensing procedures) which need coordination between a diverse set of entities in different areas. How to address environmental issues as well as motivate coastal communities to engage with the debates on the new activity and to have their voices heard, is also an important challenge.

In summary, the development of an ocean energy system **raises some major challenges** that can be summarised as follows:

i) It will entail stabilising and taking to the market a set of immature, complex technologies whose development has, so far, progressed below expectations. This will imply changing the somewhat fragmented approach to their development - followed by both actors and policy makers - and adopting a more systemic view, which also entails a more coordinated and collaborative approach to solve key problems, both technological and non-technological;

ii) It will entail achieving an effective integration between energy and ocean related actors, activities and policies. This will imply identifying and connecting, in a dynamic way, key activities and actors, achieve their alignment around common goals, coordinate actions across fields (including the policies established to support them) and work towards joint institution building.

In general terms, **these challenges call for the adoption of policies** that:

- enable a vision of future development, contributing to build legitimacy and motivating actors to adhere to the process;
- create a protected space where the new technologies can be stabilised and where new system structures - actors, networks, and institutions – can be formed and aligned (e.g. by contributing to reduce technological, market and institutional uncertainty);
- favour connections between the disparate elements that will compose the new system and contribute to align actors;
- address a variety of regulatory problems which derive from the emergence of new activities that raise new economic and societal issues.

3 SYSTEMIC POLICIES FOR OCEAN ENERGY CHALLENGES

As pointed out above, the nature of the challenges related to the development of an ocean energy system and its potential to transform the sea-related industries call for a systemic approach to policy formulation and implementation. In this context, an articulated application of some of the systemic policy instruments under analysis in this project can be particularly relevant. In this section we provide a brief analysis of the relevance of these instruments to support the development of an ocean energy system. We focus on the instruments that have been used, even if only in an "embryonic" mode, in the Portuguese case: roadmapping; pilot and demonstration; smart regulation, clustering. The socio-political and economic conditions for their application, the problems faced and the results obtained will be addressed in the subsequent section.

3.1 ROADMAPPING

Roadmaps are an important instrument for the *articulation of shared visions and expectations* regarding the future development of a technology, thus contributing to align key actors and guide their future behavior. They provide additional legitimacy to the strategies being pursued, which together with the commitment of key actors can be critical for the mobilization of resources. These features make Roadmaps particularly important in the case of technologies where there is still uncertainty concerning the future outcomes and the most adequate paths to be followed, as is the case of ocean energies. They provide a vision of future benefits and guidelines for future action, also creating the conditions for the establishment of a broad consensus among actors, which make them an important governance instrument. However, their effectiveness depends greatly on how broad is the actors' involvement in their formulation, and how inclusive is the consensus reached. When Roadmaps result from the initiative of specific industry or technology advocacy coalitions, they can have an additional role of policy lobbying.

Roadmaps have been produced for ocean energies, both at European level - where a new Roadmap is currently under development in the context of the Ocean Energy Forum, an initiative of the European Commission, as part of an action to support the development of the Ocean Energy - and at country level. In the Portuguese case, besides an extensive participation in the European initiatives, two Roadmaps on ocean energies were developed in the last 5 years, grounded on a variety of previous studies conducted over time, first on wave energy and later extending to other ocean energies. However, these Roadmaps were developed by initiative of key stakeholders, without government involvement, and as such cannot be regarded as "policy instruments". They can nevertheless be relevant from a policy standpoint: by providing an in-depth diagnostics of the situation of the field, as well as a vision on its future perspectives and on means to achieve the proposed outcomes that is shared by a broad range of actors, these Roadmaps can be used to inform policy making.

3.2 PILOT AND DEMONSTRATION SUPPORT

In the ocean energy field, experimental projects, in particular those involving test and demonstration in real sea conditions, are critical to prove technology viability, increase system performance and decrease costs. The experience thus obtained can lead to improvements at those levels, which reduce the uncertainty and facilitate access to additional capital and partners. The experimental activities associated with ocean energy systems are complex, time consuming and expensive, in particular because the final step always requires building and installing full-sized prototypes and testing them in open sea for extended periods. These experiments not only enable to test the effectiveness of the conversion technology, but also to assess the overall system capacity to withstand the harsh and unpredictable conditions in which it will have to operate. Besides *technology learning*, these experiments also permit to start putting together the whole set of activities required to manufacture, install, grid connect, operate and maintain the energy production systems, thus providing *an early blueprint of the value chain* that needs to be built, and allowing the aligning its activities and actors. They also enable to identify and address a number of *regulatory and environmental problems*, as well as issues of *community support and involvement*.

Test and demonstration activities (in particular when supported by public funds) can also be an important setting for data collection on performance of different systems/components, with a view to identify the most effective ones and avoid repetition. The effort of *systematically collecting and aggregating lessons from individual experimental projects*, achieving some form of "*meta-learning*" that can be subsequently disseminated across the field, has been pointed out as an important element in the stabilisation of technologies. This can be particularly relevant when a dominant design has not yet been reached, as is the case of wave energy.

Given the characteristics of the ocean energy technologies and their ocean location, experimental projects are *complex and extremely costly* (even at lower scales, but increasingly so for larger to full scale/longer term tests). The amount of investments needed and the nature of the infrastructures required mean that project costs are much beyond the capacity of most technology developers, requiring the involvement of external investors and a substantial financial support from governments. This problem started being addressed through the creation, at European level, of *shared test infrastructures*. These can assume the form of consortia joining organisations that install experimental facilities of various types (from basin to open sea) and make them available to their members or also to external organisations, sometimes under the coordination of supra-national entities. More recently, with the increase in the number of technologies that reach the experimental stage, several countries have directly engaged in the creation of such facilities, at least partly funded by governments or, in some cases, by European programmes. As we will see below, Portugal has also conducted activities towards the development of this type of infrastructure.

However, even if infrastructures can reduce costs and logistic problems, the investment in the development of a large scale prototype, its installation and its operation at sea during large enough periods to test resistance and performance is still very high. Thus, such projects need to be at least partly funded by public policy instruments. Given the international nature of the field, large scale experimental projects have often been funded in the context of European Framework Programmes. In addition countries may fund projects locally, either in the context of generic R&D programmes or through the setting-up of specific mechanisms to support this type of projects, particularly when it comes to pre-commercial demonstration stage.

3.3 CLUSTER POLICIES

The systemic nature of the problems associated with the development and diffusion of ocean energy technologies calls for policies that address these processes in a coordinated way, supporting the co-evolution of the various elements of the new system being formed. This systemic approach is gaining increased importance among field practitioners, being justified at two levels: i) the complexity of the technology that requires the early development of a value chain involving a great variety of activities and requiring the engagement and alignment of very different actors, ii) the fact that the new system combines activities and actors from new fields and existing industries; and that, regarding the latter, it simultaneously benefits from the experience and competences they bring, and can contribute to their revitalisation or upgrading. Overall, the fact that it is necessary to build a new system, that this system is complex, that it also draws extensively on existing activities and that it has the potential to transform some of these activities, justifies the adoption, in this field, of policies that have a "cluster" approach.

In particular, due to their expected transformative potential in what concerns existing sea-related industries, ocean energies are increasingly regarded as an element of a broader strategy that focus on achieving growth based on the coordinated development of the various economic activities related to the sea. This interdependence has been expressed, at European level, in the Blue Growth Strategy, of which Blue Energies are one pillar. A similar perspective was adopted in the case of Portugal, where ocean energies have increasingly been pointed out as an important element of a Sea Economy and related "Sea Cluster". On the other hand, the perspective of creating an "industrial cluster" has always been presented as a critical element in the national strategies for the development and diffusion of renewable energy technologies. This view can be found, from very early stages, in policy documents concerning wave energy, which always associate support to this technology with its potential contribution to develop national competences and create an industrial cluster.

3.4 SMART REGULATION

Emerging technologies raise new problems that involve different spheres of economic and social life. The presence of some of these (unsolved) problems may raise barriers to the development/diffusion of the technology, increasing uncertainty and costs. Their solution requires regulation efforts, which often involve coordination between different organisations and between different administrative levels of government.

In the particular case of ocean energies, regulation has to deal with:

- institutional aspects: private use of the sea, which is public property; conditions of access to the sea space and connection to energy distribution systems (e.g. consenting and permitting process);
- technological aspects, namely standardization which is critical for technology stabilisation;
- social aspects (also related with community support): use of spaces previously occupied by traditional activities linked to local communities (e.g. fishing); or shared by other activities (maritime transport); or used by leisure and recreation activities; or protected for environmental or historical reasons (e.g. natural reserves);
- international aspects: need to comply with international laws and agreements.

Many of these issues can occur even before the launch of commercial projects, in the scope of real sea test of technologies, conducted during in the experimental phase. They tend be addressed by government departments in a case by case basis, answering to specific requirements of individual projects. Thus, the whole process of installing and operating a system at sea (i.e. using a public space for a private activity) may require going through a set of complicated permitting and licensing procedures, managed by a variety of authorities - a complex, time consuming and often costly process for the promoters. As an example, licenses may include aspects related with: sea use (concession of public property), compliance with environmental requirements, installation (construction works and cable setting), operation, grid connection, whose authorisation lies with different authorities. These procedures tend to differ between countries, which hinder the expected international mobility. Besides formal issues, due care should be taken to prevent conflicts with the traditional activities and communities that may resent the arrival of this new activity.

The difficulties faced by technology promoters in the so called “consenting process” have been systematically presented as one of the major non-technological barriers in this field. Thus, one important step in the promotion of a favourable environment to the development and diffusion of ocean energy technologies is to approach these regulatory aspects in an integrated way, anticipating needs and devising a comprehensive regulatory framework that addressees the key problems hindering the activities of would-be promoters and is accessible and easily understood by them; while also complying with environmental and other societal responsibilities. Setting-up such a framework can be regarded as an effort towards smart regulation.

4 OCEAN ENERGY IN PORTUGAL: CO-EVOLUTION OF SYSTEM DYNAMICS AND POLICY PROCESSES

In this section we analyse in some detail the attempt to promote the development of an ocean energy system in Portugal, which was conducted in the second part of the 2000s through the definition of a strategy and the formulation and implementation of policies. This attempt was part of a broader country level effort to address two major societal challenges – the development of a more sustainable energy system and the transformation of the sea-based economy. This endeavour was translated into priority and strategic goal setting for these two areas, which contributed to frame a strategic vision for the development of the ocean energy field. The study addresses the process of formulation and implementation of policies that attempted to articulate this strategic vision adopting a systemic approach and, namely, introducing some of the systemic policy instruments under analysis in this project. The objective is to understand how an attempt at supporting a process of system innovation and transformation driven by new complex technologies took place in a specific context; and what can be learnt from it for similar processes and/or more generally for the formulation of system innovation policies.

We start by providing a brief historical overview of the process of emergence and development of an ocean energy system in Portugal. This will set the scene for the more in-depth examination of two critical periods in the system trajectory, which were characterised by significant government intervention. The analysis will focus on the interplay between policy making and system dynamics, in order to achieve a better understanding of the specific role played by systemic policies in system development and transformation.

4.1 BRIEF OVERVIEW OF THE EVOLUTION OF THE SYSTEM

In Portugal the development of ocean energies has been part of a process of transformation of the energy system, through the development and large scale introduction of *renewable energy technologies* (RET). This process started in the 1990s, with major changes in the structure of the energy system: the liberalisation of the electricity market, terminating the monopoly of the public electricity utility, which was later privatised, and authorising the independent production of energy. But it effectively took-off in the early 2000s with the definition of national strategy for RET and the introduction of specific policies to support their development and diffusion.

The strategy was influenced by European directives but also had a strong country dynamics. These dynamics were grounded on the objectives of contributing to a more sustainable energy system and reducing the high country dependence on fossil fuels. Simultaneously, it was expected that the creation of this new field would drive the development of new economic activities. Thus the introduction of renewable technologies in the energy system and the creation of a renewable energy industry became a strategic goal at country level. Over time targets were set, policies (both supply and demand) were produced and specific regulatory changes were introduced, creating a favourable environment for the development and diffusion of the new energy technologies. This permitted a high market penetration of RET, which in 2014 accounted for 61.3% of total electricity production and 52.1% of total electricity consumption[2]. This diffusion was largely based on the technologies that were closer to maturity – in particular onshore wind and more recently solar energy. But the policies and regulatory framework in place were equally applicable to less mature technologies that have also benefited from them. The economic crisis and the country bail-out led to changes in the government strategic approach to RET in the early 2010s, raising some instability in what had been until then a relatively stable supportive environment. However, RET appear to have now returned to the centre of the government strategy for country development.

Among the ocean energies, *wave energy* was included relatively early in the “package” of RETs to be developed. The early relevance of this still emerging technology was associated to the fact that the country had already developed substantial scientific and technological competences in the field. Research and experimental activities had been conducted, since the early 1990s, by a small but proactive community, with a strong position in the international scientific networks. Thus wave energy benefited from the government strategy and policies in parallel with other RETs, even if the slow development of the technology constrained its progress. But, in the mid-2000s, a greater attention started being given by the government to this particular technology, associated with the growing strategic importance attributed to the

[2] Energia em Portugal 2014, Direcção Geral de Energia e Geologia, March 2016, Lisboa

creation of a “sea economy” and to the development of a cluster around sea-related activities. It is possible to argue that a specific wave energy strategy was then formulated, which aimed at the development of a “prime mover” advantage in wave energy, entailing a somewhat pioneer approach to the development of the field: optimistic targets are set; several elements of a wave-specific regulatory framework start being established; infrastructural conditions for the setting-up of experimental, pre-commercial and commercial activities (a Pilot Zone operating as one-stop-shop facility) start being developed. The final goal is - as early expressed in RET strategies and later reinstated in the Sea strategies – to create national competences, develop an industrial cluster and contribute to revitalise and upgrade traditional industries.

The favourable environment motivates several actors, both national and foreign - from technology developers, to large incumbent companies, to firms in complementary areas along the value chain - to engage (or propose to engage) in a variety of activities in the field. There is a brief period of high expectations and intense activity. However, the delay in the actual concretisation of some of the policies/facilities proposed, combined with technology performance results below the (too high) expectations, force several technology developers to abandon their projects and lead to disappointment among both investors and policy makers, substantially reducing the fields’ attraction to non-core actors. The financial crisis hits the final blow, since those problems are compound by actors’ financial difficulties and by changes in RET policies, in particular the withdrawal of policy support to “immature” energy technologies. Projects stop and most local companies close down. The field experiences a period of decline, from which it is only now starting to recover. Along this period, only one experimental project led by a foreign company (whose early activities had started in the mid-2000s) remained in operation registering positive results and is expected to have continuity in the future. However, core national actors were able to maintain some activity, mostly in the context of European funded projects, and to retain their international networks. These efforts underpinned a recent renewal in this field, where a new generation of projects has started to emerge.

Offshore wind appears later in the process. Contrary to wave energy, there is practically no activity in this field in Portugal (although there is intense activity in onshore wind) until the decision of a large domestic actor to launch, in the late 2000s, a project to develop a new technology for deep-waters. This is an emerging technology (a floating system), developed by a small foreign company, in an area where no technology is yet in the market; and the expectation is, once again, to achieve technological and market lead. The genesis of this project is contemporaneous with the period of high expectation in wave energy – indeed its promoter is then also very active in that field - and thus it is regarded as also contributing to the goal of creating an industrial cluster around sea-related activities. However, its actual development already takes place by the end of the decade, when wave energy is experiencing problems, and coincides with a period of financial crisis and government divestment in RET.

Despite these shortcomings the floating offshore wind project – which was (and remains) the only offshore wind activity taking place in the country – managed to progress and achieve very positive results, which increased its credibility towards policy makers. It benefitted from generic RET policies and regulation already in place, and also from the regulatory processes being conducted to address ocean-specific issues raised by wave energy. But the delays in these regulatory processes left several open problems. To solve them required the promoter to deploy its substantial credibility and political power which, in some cases, effectively drove the formulation of policies/regulations with impact on the whole ocean energy field. The presence of this project, which became a “flag project”, was important to sustain the idea that ocean energy could still be a relevant field in the Portuguese economy, both among policy makers and among other national actors, who were involved in its activities over time.

There is currently a renewed political interest in the development ocean energies, the focus being on the two technologies that registered some development in Portugal: floating offshore wind and wave energy. This renewal is once again driven by both national and European (e.g. the Blue Growth Strategy and more specifically the Blue Energy Action) dynamics. At national level, the field may once again benefit from the strategic roles attributed to energy and the sea in the country development. In what concerns the Sea, ocean energies are now an important element in the revised National Strategy for the Sea and its Action Plan. In what concerns Energy, ocean energies have less visibility, although support to this category of renewables (namely to experimental activities) is explicitly considered in operational programmes concerned with Sustainable Development. However, even if both areas refer to the relevance of Ocean Energies in their strategies, the field still tends to be relatively marginal. In the case of Energy, because it is the most immature technology, not yet close to the market, in a context where other RETs are progressing faster. In the case of the Sea, because it is an area of "potential development" in a context where other sea-related activities have an intense economic activity and/or pressing problems. A recent decision by the government to set-up an Inter-ministerial Working Group whose experts should define a "model of development" for the ocean energies area can be an important step to address this problem, eventually driving some policy changes in the future.

4.2 ANALYTICAL APPROACH

The approach adopted to analyse the role played by systemic policies in the development of an ocean energy system in Portugal is grounded on the notion that, in order to effectively understand how policies influence system innovation and transformation, it is necessary to assess not only their direct impact on system formation and development, but also how the dynamics of the system affect policy formulation and implementation. Thus, the analysis is centred on the interplay between policy making and system development, aiming at understanding how policies/policy processes and actors' strategies and practices co-evolve, mutually affecting each other's evolution, and how this co-evolutionary dynamics transforms their environment.

In what concerns the process of policy formulation and implementation we draw on the conceptualisation of policy mix proposed by Rogge and Reichardt (2016)[3], who define the policy mix as consisting of several elements: a policy strategy; a mix of instruments; policy processes, i.e. policy making and implementation; and also identify a number of critical policy mix characteristics (e.g. consistency of elements, coherence of the process; comprehensiveness and credibility of the policy mix; and stability).

The concept of policy mix is pertinent when analysing the complex transformation processes taking place in the ocean energy field. In fact, the characteristics of the emerging system and the nature of challenges to be dealt with (section 2), mean that it is crucial to design a comprehensive and coherent set of policies. Moreover, given the unpredictability of emerging system behaviour (subsection 4.1), policy design needs to be responsive to system evolution, and to sudden changes resulting either from unplanned outcomes of policy application or from unexpected events internal or external to the system.

[3] Rogge, K. S. and K. Reichardt (2016). Policy Mixes for Sustainability Transitions: an extended concept and framework for analysis. Research Policy 45 (8):1620–1635.

Following this framework, when analysing the Portuguese case we will first of all assess the presence of a strategy for the ocean energy area – i.e. policy objectives and principal plans to achieve them. At this level, and having in mind the transformation goals associated with this field, we will also attempt to understand the broader drivers behind the strategy, in particular whether it fits with more far reaching strategic objectives, defined at country level, to address major societal challenges. We will subsequently identify the policy instruments that were defined to translate this strategy into action and will address the process of their formulation and implementation (and eventual revision). At this level we are particularly concerned with the effectiveness of the policy process, i.e. whether the strategic objectives and plans were effectively translated into a comprehensive policy instrument mix and whether the policy instruments devised were effectively implemented. At a more general level, we will also attempt to ascertain whether system stakeholders were involved in the process of strategy definition and policy formulation.

In the following sections we analyse the attempt to develop an ocean energy system in the Portugal over the past two decades, focusing on the co-evolution between policy making and the dynamics of the emerging system, with a view to understand how they influenced each other over time. That is, we are concerned with the influence (positive or negative) in the system of both the actual policies (the policy mix), and the process of their formulation/ implementation (namely delays, problems, reversals at this level). But we are also concerned with the influence (positive or negative) of the dynamics of the system in the process of policy formulation/ implementation. We also take into consideration the impact of external shocks at two levels. First, as factors that may influence system behaviour in unanticipated ways, producing unexpected outcomes and requiring substantial policy re-orientation. Second, as factors that may impact on the policy process, influencing the ability to implement policies (from specific instruments to overall strategies) and eventually leading to substantial policy changes.

In order to better understand the processes described above we look in detail into two main periods in the (somewhat troubled) development trajectory of the ocean energy system - a period of strategic focus and system growth, and a period of policy divestment and system crisis:

1) **Strategic focus and system growth**: period characterised by a strategic focus on the development of ocean energies that involved active policy making with a strong impact on the system behaviour; but nevertheless confronted with some difficulties, not always achieving the expected outcomes, both in terms of actual policy implementation and in terms of results obtained.
   In analysing this period we want to understand the drivers behind the emergence of a strategic vision for the field and how it was translated into a coherent policy mix. This will also enable us to address in greater detail the contents of that policy mix, that is, the nature and objectives of the set of instruments devised and their interdependencies. At this level particular emphasis will be put on the conditions (at policy and system level) that drove the adoption of a systemic approach to policy formulation and the (sometimes tentative) introduction of a number of systemic policy instruments, or their "embryos". We also want to understand the impact of the policy mix upon system development and the feed-back to the policy process. Finally, we will identify some difficulties associated with the implementation process.
2) **Political and policy divestment and system crisis**: period in which the strategic focus on the field disappeared and support to its development was considerably reduced, a situation partly driven by difficulties in the political process (that had already started emerging in the previous period), but considerably aggravated by external shocks that led

to broader changes in country strategic priorities; but where some advances were nevertheless achieved, paving the way for a (slow) recovery.

In analysing this period we want to highlight the difficulties associated with the actual implementation of the policies and particularly, in the case of systemic policies, the problems arising from gaps in the implementation of the full policy mix. We are also interested in uncovering the system level efforts towards recovery and the influence of these efforts in policy (re)formulation.

Along this analysis we address in greater detail some specific systemic policy tools: smart regulation, pilot & demonstration support, cluster policies and roadmapping, and also less traditional innovation policies such as demand-side mechanisms. We discuss:

i) whether they were considered in the policy mix and in which forms;
ii) whether they were implemented;
iii) which were the eventual problems in their definition/implementation;
iv) which appeared to be their impact on the system (individually and in terms of their interaction – or lack of – with other instruments);
v) which were the main difficulties or missing elements identified.

The overall analysis provides some evidence of the interplay or co-evolution between system events and policy making, both in "up" and in "down" period, contributing to a better understanding of the processes underlying the introduction of systemic policies. It also offers some insights into the non-linear and often troubled process of policy formulation and implementation, in cases that entail complex system transformation.

4.3 STRATEGIC FOCUS AND SYSTEM GROWTH

4.3.1 Emergence of a strategic vision

The emergence of a strategic vision for the ocean energy in Portugal, in the mid-2000s, had its roots in a combination of factors that conflated in the identification of an industrial transformation opportunity based on the emerging wave energy technology, where early efforts were centred. As pointed out above, Portugal had been developing some capabilities in this field during the 1990s/early 2000s. Given the still immature stage of the technology, the focus was on research and early experimental development, mostly conducted by research organisations. These activities were largely supported by European level RTD projects and permitted the *creation of good scientific and technological competences and extensive international networks.* The efforts conducted in the field were also encouraged, at country level, by a government policy that promoted the development of RETs. This was namely expressed in the setting-up of *ambitious long-term targets* for capacity installation by technology, including wave energy. Even if these policies were more effective in the case of technologies closer to the market (e.g. wind), the creation of new *business opportunities* in the renewable energy field produced a positive attitude towards RET and generated a set of companies potentially interested in investing in other renewable technologies. A particularly important actor in this group was a *large incumbent – the main energy utility* – that revealed an early interest in following-up the developments of wave energy technologies. As such, it became involved with the first experimental projects conducted in the 1990s, bringing resources, networks and legitimacy to the new field.

By the mid-2000s a number of developments had taken place, as a result of these efforts, that raised the government attention to the wave energy field. In what concerns the technology, the assessment of wave energy resources potentially available and the early experimental activities conducted in Portugal and abroad had created positive expectations regarding its future evolution, among public and private actors. In fact, a number of technologies in different countries were *moving to full scale demonstration* in real sea conditions and there were *high expectations* regarding an acceleration of technology upscaling and commercial deployment. These advances were also acknowledged by the European Union, which was increasing its support to wave energy field, and conducting activities aiming at the definition of a strategic vision for the field and an agenda for its development.

At country level, the advocacy activities of a *very proactive research community* were reinforced by the *creation of a collective organization* that brought together the main field actors – public and private – speaking for the field and becoming a key interlocutor to the government. This collective organization was asked by the government to conduct a study on the wave energy field, which would significantly inform subsequent policy making. The study provided a first assessment of the country conditions and opportunities and offered a strategic vision for the development of the field. According to this vision, the conditions found in Portugal - *natural resources* and *extensive scientific and technological competences* - and the *favourable policies for RET* could make the country an attractive location for the promoters of the most advanced technologies (originating from different countries) as they were launching full scale experimental projects aiming at technology upscaling. An involvement at this stage could provide a "first mover advantage" in the new field, enabling the country *to position itself as a central location for wave energy production* when some of these technologies reached the commercial stage. This could also *drive the creation of a supportive industry* around this new activity (*a "wave energy cluster"*), combining new and existing sectors.

The opportunities that appeared to emerge from the development of this technology *matched the priorities defined by the government strategy for the energy field*. They equally matched the objectives of a strategy that was starting to be devised to answer to another societal challenge: the *development of a sea economy*. This would be enabled through the creation of new activities related with the revitalization of traditional declining sea-related industries and associated transformation of other industries. Energy production was regarded as one such activity.

This vision underpinned the policy process that took place in the following years in Portugal. The strategy and policies formulated for the field of wave energy were thus supported by a **combination of expectations** regarding: **the prospects of an acceleration in the development and diffusion of the wave energy technologies**; and what was identified as **country-level conditions and capabilities** to contribute to such acceleration, as well as the opportunities created by an **early involvement in that process**. Further legitimacy was achieved by the fact that such opportunities **matched broader country goals concerning two major societal challenges - clean energy transition and development of a sea economy.**

In order to fully achieve this endeavour it was necessary to define an adequate set of policies that would reinforce the favourable conditions and address the main obstacles. This policy making process started in the mid-2000s.

Box 1 provides a summary of the main system and policy level conditions underlying the emergence of a strategic vision for the ocean energy sector. It highlights the co-evolutionary relationships between the processes taking place in the political environment and those taking place at system level, as well as the role played by the latter in the formulation of a strategy for ocean energies.

Summary Box 1. Co-evolution of system and policy level conditions: emergence of a strategic vision

System level conditions	Policy level conditions
Advances at the technological level (actual or forecasted) raise expectations on potential future contribution of ocean energies to sustainability and economic development. Positive experience with other renewable energies creates favorable environment in economy.	Definition of broader country level strategies that address major societal challenges related with energy - clean energy transition; and the sea – development of a sea economy. Policy support to other (more mature) renewable energy technologies is showing some success.
System actors aggregate information on system development/articulate a vision of future benefits and convey this vision to powerful actors - whose support increases field credibility and political influence - and to policy makers.	Policy makers consult with system level actors and identify a match between the vision proposed for the wave energy field and the broader strategic goals.
Co-evolution: emergence of a strategic vision	
Interplay between system dynamics – technological advances in wave energy and system actors' intense advocacy - and policy initiatives – country priorities formulated in matching areas and government willingness to consult with system actors to define strategies to pursue them – conflate in the identification of an opportunity for new industrial development/transformation based on the emerging wave energy technology. Conditions are created for the development of a strategy for the field, which will underlie the intense policy making taking place during the "strategic focus" period.	

4.3.2 Policy formulation – designing an adequate policy mix

The strategic approach to the development of renewable energies related to the ocean was partly grounded on the overall country bet on renewable energies and partly related with the specific opportunities associated with its sea location. Thus, the broad strategic objectives and the narrative of future benefits to be achieved were stated in the National Energy Strategy that defined the goals for the various RETs and in the National Strategy for the Sea. More specific objectives were not always included in these documents, but were subsequently described in the preamble of various pieces of legislation for the field. This legislation formulated more precisely policy goals such as attempt at field leadership, wave energy cluster development and industrial transformation, and the ways to achieve these goals.

The strategy was translated, first of all, in the setting-up of an ambitious future target for wave energy production, which signalled stability in political commitment and provided an incentive for technology developers and investors. Given the stage of the technology, *experimental development* was identified as a critical activity and therefore the area in which the greatest efforts should be made. The support to experimental activities was seen as a means of enabling technology developers (national and foreign) to test the technical viability of their energy conversion systems and to improve their performance in economic terms. Pilot projects and demonstration facilities could also provide the setting where a new industrial value chain would start being configured. Thus, it is possible to argue that support to experimentation with a view to developing a future industrial activity was at the core of the policy formulation in this period.

However, as pointed out in section 2, the conduction of experimental activities in the ocean energy field – in particular as systems move towards larger scale experimentation in real sea conditions – confronted a number of problems: high upfront costs at a stage when the technology is not yet proved, high operational complexity and need for specific infrastructures, need to bring together a great variety of activities and competences (that often go beyond the specific expertise of the technology developers), regulatory and societal problems associated with access to the sea space. Several of these problems effectively arose at the system level and, given their nature – complex, interconnected – could not be solved solely through traditional R&D support mechanisms, which focused on specific parts of innovation system. Hence, a systemic approach to policy formulation became crucial. This approach attempted to anticipate and address the main difficulties and reinforce the existing strengths, in an integrated way, thus moving beyond the previous approach that was mainly reactive to specific problems arising from individual situations.

The policy mix devised comprised different types of instruments: pilot & demonstration support and regulatory measures were combined with demand side mechanisms and more traditional R&D support. But the most relevant feature was the attempt to build a comprehensive and coherent policy framework. A focal point in this framework was the creation of a shared test and demonstration facility – a Pilot Zone for Wave Energy – that provided the essential infrastructure for the experimental activities and was the setting for a comprehensive regulatory system for the production of electricity from waves. The latter included regulating the use of the sea for this activity (which was part of a broader process of Marine Spatial Planning) and the definition of the regime under which such electricity production could be performed. It also included streamlining the permitting and licensing procedures that were so far dispersed by a variety of administrative entities.

The infrastructure proposed was innovative in many respects. First, its legal regime was very broad as it would accept projects along different stages of development: test (to demonstrate that a certain concept or technology is technically and economically viable); pre-commercial (for technologies whose technical and economic viability have been established but that need further improvement to make them financially self-sustainable); commercial (projects ready for commercial operation); being the first to have this broad scope. Encompassing all stages was important because the promoter was not required to go elsewhere when scaling-up the technology. Second, the operation regime was also novel, since it endowed the Pilot Zone managing authority with the responsibility for implementing the legal regime defined for wave energy production, putting all the administrative procedures – including the complex installation permitting process and grid connection issues – under the authority of one sole entity that acted as a "one-stop-shop". This entity was the organisation responsible for managing the electricity grid at country level, which also safeguarded the potential grid integration problems of a new and intermittent technology.

These more procedural aspects were combined with the regulatory framework already set-up for renewable energy production, that included demand-side incentives. That is, projects that were accepted and required connection to the electricity grid benefited from a "feed-in tariff" mechanism: promoters could inject electricity into the grid, up to the amount contracted, at a special tariff that was adjusted to the nature (stage of development) and size of the project. This tariff was maintained over a guaranteed period, thus sheltering promoters from the competition with established technologies. The feed-in tariff is in fact a form of subsidy, reducing the uncertainty associated with the installation of immature technologies that have extremely high capital requirements already at the pre-commercial phases and that, even upon reaching early commercial stages, will still produce energy at a non-competitive cost.

Finally, R&D and experimental activities being conducted in this field could apply to support from generic R&D and innovation support mechanisms that were part of National Operational Programmes to promote S&T and Innovation, and which provided financial grants to a wide typology of projects, often privileging collaborative projects. The specific Programmes that were active during this period (POE/PRIME and QREN) also included a specific mechanism to finance large scale pilot and demonstration projects. In addition to national programmes (that inevitably had limited budgets), it was expected that technology promoters could also resort to European funded programmes, in particular the RTD Framework Programmes (where ocean energies had started gaining some attention), whose access was facilitated by the transnational nature of most activities conducted in the field.

Thus, the instrument mix being devised was relatively comprehensive, even if some of the instruments were not specific for this particular field and, therefore, actors had to compete for support with other areas. The systemic nature of the policy mix designed was reflected in its capacity to address a broad range of relevant issues and systemic problems. However, it was not without flaws. The main missing elements were mechanisms that would promote the expected development of industrial competences, namely the orientation of existing firms/industries towards the new field. So, the “creation of an industry” based on wave energy production was mainly a goal and no specific instruments were devised at this level. It is possible that policy makers were following the model applied in the case of onshore wind, where such instruments were introduced when the technology was mature enough to provide effective market opportunities. At this stage, this was not the case for wave energy, despite developers’ promises.

In what concerns the process of policy formulation, it is relevant to mention that there was extensive consultation with stakeholders and that the definition of instruments was at least partly grounded on system diagnostics and forecasts produced and on proposals made at stakeholder level: for the Portuguese case by the collective organisation formed in the field, and at European level, in the context of several transnational projects and organisations (in which Portuguese actors also participated). There were also some attempts at coordination between government areas and departments (in particular, but not exclusively energy and the sea) for “transversal” issues.

Table 1 – Policy mix formulated during strategic focus period

Policy	Description
Policy Strategy	Long term horizon: "narrative" concerning role of wave energy to achieve broader societal goals; ambitious energy production long-time target
Instrument mix	
Smart regulation	Coherent regulatory framework that seeks to address the main regulatory problems arising at the innovation system level in a coordinated way (need to articulate different areas and consider the requirements of different stakeholders; need for coordination between different government departments)
Pilot & demonstration	Experimental development identified as central given the stage of technology and particular problems it confronts in this field. Experimental facility that can encompass different types of projects in different stages of development and is associated with a number of objectives in terms of learning from experimental activities; combined with (generic) financial support mechanisms for demonstration projects.
Articulation between regulation and experimental activity	Experimental facility acts as focal point for policy, combining in a novel way the function of physical infrastructure for test and demonstration with the overall coordination of the activities related with energy production from waves.
Demand side incentives	Special tariffs & priority of dispatch: reduce uncertainty to investors; avoid competition from established energy technologies.
Cluster policies	Creation of an industrial cluster around technology (involving new and existing industries) as policy goal. But no specific instruments were devised, neither to motivate companies in complementary fields (industry development goal) nor to promote cluster development.
Traditional R&D support policies	Generic mechanisms to support public, private and collaborative R&D: generic programmes at national level. Combined with access to European RTD programmes.
Traditional innovation support policies	Mechanisms to promote RET development in general. Generic mechanisms to support innovation.
European level programmes	R&D and experimental activities expected to resort to complementary support from European level programmes (large projects; transnational partnerships in highly internationalised field; EU increasing attention to this field).
Policy processes	
Foresight/policy intelligence	Mostly provided through stakeholder consultation: collective organisation that groups main stakeholders and also acts as bridge to intelligence produced in transnational organisations at European level.

4.3.3 Policy implementation and system behavior

The set of instruments described above, when implemented, would create an effective "protected space" for the development of the technology, removing several barriers to technology scale-up and diffusion. However, their implementation was far from being a smooth process, despite the government commitment. Thus, while some legislation started being produced, the full implementation of the whole mix experienced several difficulties related with: the novelty and/or complexity of some instruments; the fact that implementation often required coordination between different government areas; the interdependencies between some of them, which meant that operability depended on their combined implementation. These difficulties were both operational and political. So the process was uneven and some critical instruments ended up being very slow to come out, or were never fully implemented.

Despite this, the sole communication of strategic goals for the field and the announcement of the intention to launch a number of new policy instruments (in particular the novel combination of pilot & demonstration infrastructure and regulatory framework) already had a positive influence on system behaviour. They offered guidance and legitimacy and thus provided an incentive for existing and new actors to engage in the new field. This effect was reinforced by the presence of demand side incentives for RET (tariffs) that had proved effective with the renewable technologies already diffusing. The government commitment to wave energy was regarded by actors as part of the country's stable bet in renewable energies, being perceived as potentially providing opportunities similar to the ones that had emerged during the previous (positive) experience with wind energy.

The combination of high expectations concerning the facilitating roles to be played by the policy instruments announced, with the also high expectations regarding a fast progress of the technologies being developed, created an environment favourable for investment in the wave energy field. This produced one of the expected outcomes: the attraction of foreign actors to develop their technologies in Portugal, also as result of the proactiveness of the more internationalised Portuguese actors. It also motivated local scientists to start moving their technologies out of the laboratory and create new companies to pursue with their development. Finally it attracted the attention of both large energy companies and established companies from other sectors that had already invested successfully in the wind energy, or that were willing to move into the renewable energies area. This group of actors saw the experimental projects being launched/ proposed as an opportunity to gain some position in a new field full of potential, and the policies being announced as considerably reducing the risks of doing so.

These processes and the activities they generated at system level created a momentum that at some point gained some "hype" characteristics, influencing the policy process. In fact, there was a change in the government attitude towards the development of wave energy. There was a visible pressure for achieving fast results and, as a result, the staged approach to the development of a variety of different technologies was largely overlooked, as political attention focused on one project that promised immediate commercial outcomes. This move was followed by several large industrial actors, possibly also encouraged by the strong government endorsement. This political option would have an important impact upon the subsequent developments at the policy and system level.

Box 2 summarises the key drivers at work during this period at system and policy levels and highlights the co-evolutionary relationships between the processes taking place at both levels and the way they affected each other. Of particular relevance are, on the positive side, the influence of a clear vision for the field and of the perceived government commitment on system actors' behaviour, leading to system expansion; and, on the negative side, the effect of the too high expectations this induced (as compared with the system capacity to fulfil them) on policy processes, leading the strong dependence of the field on policy decisions, dependence which had a distorting impact on the system.

Summary Box 2. Co-evolution between system and policy level drivers: strategic focus period

System level drivers	Policy level drivers
Growing actors expectations regarding the pace of (wave energy) technology development and its future impacts on economic activity Expectations increase the field attractiveness to a range of new actors (large companies & other investors)	Growing country's strategic bet on RET Ocean energy included in National Strategy for Sea Definition of wave energy strategy combining energy (industrial cluster) and sea (sea economy) strategic goals. Formulation of a coherent policy mix (see Table 1)
Several experimental projects (involving national and foreign actors) are launched or negotiated	Difficulties/delays in the implementation of some components of policy-mix
"Hype" situation starts to emerge: e.g. expectations rise too high (especially among external actors) when compared with the system capacity to fulfil them.	Government political options for the field influenced by "hype" environment.
Co-evolution: strategic focus	
Communication of strategic policy goals and announcement of policy instruments is a major driver of action at system level, even before effective policy implementation. Policy provides a strategic vision for the future system development and offer legitimacy, motivating existing and new actors and driving system expansion. Growing activity at system level and positive expectations attract greater attention from policy makers. Expectations grow on both sides: at policy level they are fueled by promises made by technology developers; at system level by the legitimacy bestowed by the government growing "bet" on the field – leading to a "hype" situation that affects decisions by investors and policy makers. Government options for wave energy development interfere with system behavior: strong government support to individual project that promises faster outcomes ('picking the winners' approach) is detrimental to alternative projects; sends a signal to large investors that follow the move.	

4.4 POLITICAL DIVESTMENT AND SYSTEM CRISIS

4.4.1 Policy processes and external shocks

The policy processes that emerged by the end of the decade – partly influenced by the dynamics of the system, but also resulting from the particular reaction of policy makers to these dynamics - would have an important impact on the subsequent trajectory of the field. These effects would also be magnified by the advent of the financial crisis – an external shock that had unforeseen impacts at both system and policy levels.

In what concerns the policy processes, *the change in the government approach*, coupled with the *high expectations created around one sole project*, left the system highly vulnerable to the *intrinsic uncertainty of technology development processes*. Thus, the failure of that "flag project" had a strong impact, driving a process of *disappointment at political level*, which led to a slowdown in the implementation of the policy mix devised. The decline in political commitment also had an impact at the system level, contributing to accentuate the effects of the, then evident, *lower than expected performance of the technologies*. But an *external shock* – in the form of the financial crisis – was an additional factor that substantially aggravated these problems. It increased the difficulties being experienced at system level, stopping projects, driving away investors and further reducing the field relevance in political terms.

The financial crisis also had a profound impact upon the broader country strategy regarding RETs, driving major changes in an area that had so far registered a remarkable political stability, but now suddenly faced divestment. In the particular case of wave energy, the strong policy influence on the development of the field caused additional political instability, which aggravated these effects. In fact wave energy experienced the so-called "bandwagon and circus dynamics" (Verbong et al. 2008)[4]: policy makers jumped on the bandwagon of wave energy when they believed that chances for success were high; these chances becoming more apparent through attractive political narratives (e.g. country's leadership in renewables, increase of jobs, opportunity for sea industry transformation) and regulatory changes that directly impacted on projects potential feasibility and actors expectations. However, when at some point the low cost-efficiency of the technology became evident – in this case accentuated by the financial crisis - policy makers left the wave energy bandwagon and the "circus" eventually moved to another domain of interest.

This combination of negative effects at system and political level reinforced each other over time, leading to an almost complete halt on policies related to wave energy and an effective policy divestment in the field (clearly expressed on a great reduction of the long term wave energy target). Thus policy processes did impact upon the effectiveness of policies, while external shocks contributed to aggravate the negative effects already at work. The result was a system crisis, manifested through a sharp decrease of activity in the wave energy field and the shrinking of the emerging system. It should be noticed that while governments can have a role in counteracting system-level problems in periods of crisis, we observed here a situation where government behaviour was one of the factors that contributed to aggravate these problems.

4.4.2 Attempts at recovery – towards a new system configuration

However, system level events did once again introduce some dynamics in the process, driving a change in the system trajectory, in the 2010s. This took place though the *introduction of an alternative ocean energy technology*, potentially more mature (*floating offshore wind*), this time proposed by a different type of actor: a large incumbent company (energy utility), that had so far been involved in wave energy projects mostly as "observer", but was now willing to lead in the new field. Although the project was launched in the "downside" period, the credibility and political power of this actor made it possible to overcome some resistances due to the previous negative experience, driving some renewal of policy making for the ocean energy area.

The new field was not fully encompassed by the previous policy regulation (focused on wave energy), thus requiring specific legislation. It also required addressing a number of problems, transversal to all ocean energies, but not yet fully solved due to the halt on policy implementation. New legislation started being produced to address some of these issues, but the approach was now fragmented, policy initiatives being mostly reactive to specific problems arising in individual projects. Even if some of the piecemeal policy elements produced during this period had relevance beyond the project that triggered them (thus adding to the overall regulatory framework), the systemic approach to experimental development/technology scale-up and associated industry creation was effectively abandoned. In particular, some central elements of the strategy devised in the mid-2000s – e.g. the experimental infrastructure and associated regulatory framework - were never fully implemented.

The emergence of the new field and the launch of a large scale experimental project have nevertheless opened new opportunities, both for organisations previously involved in wave energy and for new actors. This namely enabled some activity/skills development by actors in areas located downstream of the value chain at a period when wave energy projects had

[4] Verbong, G., F. Geels, and R. Raven. (2008). Multi-niche analysis of dynamics and policies in Dutch renewable energy innovation journeys (1970–2006): hype-cycles, closed networks and technology-focused learning. *Technology Analysis & Strategic Management* 20, no. 5: 555–73.

almost disappeared (only one experimental project remained active). It also drove some reconfiguration of the system under construction, with a greater integration of activities between the wave energy and offshore wind. This was namely mirrored in the transformation of the wave energy collective organisation, which expanded its scope becoming the association for "Offshore Energies". Under this umbrella, system actors engaged in a number of activities with the objective of rebuilding a vision for ocean energy and restoring its political credibility.

Of particular importance at this level was the production of two Roadmaps on ocean energies. They were developed with the goal of devising ways of accelerating the adoption of the new technologies. For this purpose, the Roadmapping exercise adopted a systemic approach that addressed ocean energies as a whole and considered in some detail the value chain, i.e. the whole set of activities that would encompassed by the development of an ocean energy sector. These Roadmaps were developed using a "bottom-up" approach, i.e. they were led by a group of system actors - from research, industry and the civil society - while policy makers were only involved in the consultation stage. Thus, rather than being "policy instruments", they should be seen as a means of informing policy making or supporting policy lobbying. This role is clearly expressed in the documents produced, which mentioned that the vision expressed in the Roadmap needed to be "adopted" by policy makers, and indicated a number of areas where government intervention was necessary for achieving the goals defined.

These efforts were important at system level for actors (re)engagement and guidance, but they appear to have had limited political impact: the government did not express an interest in endorsing the proposals or discussing the results, even if some legislation produced afterwards have responded, to a limited extent, to some needs expressed in the policy recommendations.

4.4.3 Alternative approaches to system development - policy re-orientation

One further element that contributed to sustain the field was *the activity taking place at a different political level: local/regional*. *Local authorities* had already been instrumental in the attraction and installation of one of the early experimental wave energy projects. In this case, the local authority created the necessary conditions for project installation when regulation for the field was still absent and assisted the promoters in the access to support mechanisms as they become available. It also played an important bridging role over time, promoting connections with organisations from the region, which become increasingly involved in the various generations of the technology being tested, as suppliers and service providers. Such involvement led some local companies to extend their activities, create new competences and also develop international networks. That is, local policies enabled the creation of opportunities for the revitalisation of existing industries through the engagement with the new technology. This wave energy project was the only one that resisted in Portugal during the period of decline, advancing to the pre-commercial stage. While this was only possible due to funding from European RTD programmes and foreign investors, the project promoter also benefitted from the continued support of the local authority. This was particularly relevant at a period when the central government had lost interest in ocean energies, and was especially wary of wave energy, attention being focused on the offshore wind project proposed by the large incumbent. This example started being followed by other regions, although in a more limited scale. For example, local authorities from the areas where the experimental offshore wind project was installed also started revealing some interest in these activities. Moreover, as part of the design of the Regional Smart Specialization Strategies (RIS3), several regions have included ocean energies in their priority areas.

At the policy level, another fundamental aspect was a change in the strategic environment for ocean energies, through the reinforcement of their link with the *Sea Economy,* and a greater association of the emerging ocean energy technologies with the development and revitalization of sea-related industries. In contrast with the political instability regarding renewable energies, which substantially weakened the field's fit with energy as a societal challenge, the Sea continued to assume a central role in government strategies, also receiving an increasing attention from a variety of economic and social actors. Thus, the opportunities for the development of ocean energies became increasingly associated with their inclusion in a Strategy for the Sea and with the policy initiatives originating from that government area.

The activities conducted at this level have namely addressed one of the gaps in the policy mix defined during the "vision period": the creation of conditions for cluster development. As pointed out above, the cluster perspective had been present in the policy discourse for RETs from the early stages. But, at the time, the ocean energy system was too emergent to benefit from cluster-oriented instruments set-up for more mature RET, and no specific instruments were devised for its particular case. The creation of a Sea Cluster was also a central goal in the strategy for the sea, the focus being on the integration between the different types of sectors – both existing and new – that could contribute to the transformation of the sea economy. This approach enabled the new ocean energy field to benefit from some policy initiatives promoted at this level.

Of particular relevance was the creation of a Cluster Platform: the "Sea Knowledge and Economy Cluster" (OCEAN XXI), which encompassed ocean energy as one element. This platform was created under a generic instrument introduced in the late 2000s - Strategic Initiatives for Collective Efficiency, defined as "a coherent set of initiatives, promoted by a collective of companies (at national, regional or local level) with innovation, qualification or modernisation goals; that enable the emergence of agglomeration economies, through cooperation and networking among the companies and between these and other relevant actors". It supported the creation of collective organisations with different scopes (but whose members shared a vision and defined an Action Plan) that benefited from specific incentives to conduct networking and coordination activities. The integration in this platform permitted to start identifying potential interdependencies with other cluster components (e.g. other fields and industries), particularly at regional level. The still emergent nature of the ocean energy field inevitably resulted in a relatively marginal position in such a broad and complex cluster. Nevertheless, these activities led to a greater awareness of opportunities created by the new field among other cluster actors and permitted some steps towards collaborative processes.

The growing association of ocean energies with the sea as a major societal challenge enabled the field to recover some political credibility and to maintain some activity. However, the continuous political disengagement of the energy area – even if moderated by the support awarded to the incumbent initiative – was still problematic, effectively delaying or halting several processes underway. At system level this had a damaging effect upon a fragile system, still being formed. At political level it prevented the full implementation of the policy mix, even if some of its elements were set in place. It also had a negative impact on subsequent policy making attempts conducted by the Sea area, inhibiting the necessary coordination between the two government areas.

Box 3 summarises the key drivers at work during this period at both system and policy level and highlight the co-evolutionary relationships between the processes taking place at the system and policy level. Of particular relevance is, on the negative side, the way policy processes hindered continuity of policy implementation and contributed to aggravate system difficulties, leading to greater system decline; and, on the positive side, the way system dynamics – through actor proactivity and system reconfiguration capacity – were instrumental in restoring political credibility, inducing some policy-reorientation, namely through the involvement of different policy levels and areas.

Summary Box 3. Co-evolution between system and policy level drivers: political divestment and system crisis

<table>
<tr><th>System level drivers</th><th>Policy level drivers</th></tr>
<tr><td>Failure and termination of wave energy ‘flag’ project.
Unfulfilled (inflated) expectations lead to disappointment and abandon by external actors.
Decline of wave energy field.</td><td>Political disengagement from field, following hype and disappointment process.
Impact of financial crisis: policy divestment from renewables.
Fit with energy as societal challenge is lost</td></tr>
<tr><td>Emergence of new offshore wind technology.
Incumbent takes lead in the new field.
Large scale experimental project maintain some activity in field.</td><td>Ad-hoc legislation answering to individual project needs; resulting in fragmented policy framework.
Envisaged policy mix never fully implemented; effectiveness greatly reduced (interdependences).</td></tr>
<tr><td rowspan="2">Continuity in experimental activities (albeit limited) and inclusion in Sea Cluster Platform provide setting for some interaction between different sectors and for some learning processes along the value chain.</td><td>Ocean energies more decisively in Strategy for the Sea, benefit from policies at this level: Sea Economy becomes driver of some recovery</td></tr>
<tr><td>Local/regional political activity plays some role in sustaining activity in wave energy.</td></tr>
<tr><th colspan="2">Co-evolution: political divestment and system crisis</th></tr>
<tr><td colspan="2">Hype and disappointment processes have damaging effects at system and policy level. At policy level they interfere with policy implementation, delaying the set-up of key elements of policy mix and/or inducing changes in the (so far systemic) policy approach.
Political processes and system difficulties self-reinforce (negatively) each other over time, leading first to abandon of an integrated strategic approach to policy, then to deceleration and almost halt to policy implementation, with impact on field credibility and performance.
External shocks impact both system development and policy strategies: financial crisis causes major changes in government attitude towards renewables: divestment has stronger impact on less mature technologies – withdrawal of support and field decline.
New field dynamics (resulting from entry of powerful actors and “resistance” of existing ones) and growing strategic fit with Sea as societal challenge associated with some recovery at system level and renewed interest at political level.
Engagement at local/regional policy level – support local embedding of emerging technologies and create opportunities for local industry development/renewal.</td></tr>
</table>

4.4.4 Towards system renewal?

As a result of these developments, the ocean energy field started experiencing some renewal, in what concerns both system level activity and political attention. Underlying this renewal is once again the interplay between system dynamics and policy processes. At system level we can pinpoint the *persistence of core actors* in maintaining activity and lobbying efforts, and their capacity to reconfigure the system, as well as the role assumed by a *powerful incumbent* that moved from an “observer” to a *leading position*. At policy level we can stress the growing perception of the relevance of the energy field as one key element in the development of the sea economy, which provided again a broader strategic fit to the field. We can also point to some role being played by the regional policy level, which has become increasingly relevant in the current policy formulation. Finally it is also worth pointing out the influence of European level policies, where ocean energies have become increasingly important, benefitting from a broad range of policy instruments.

In what concerns future perspectives, it is worth mentioning that, with a new change of government, renewable energies gained once again an important position in the strategy for country development. This change is too recent to have produced direct results, but there are indications of new strategy definition and policy formulation for the ocean energy field. This continues to be led by the Sea area, which has assumed an even stronger position in the new government strategy, but there is evidence of attempts to coordinate with the energy area (and other areas such as environment or science).

Thus, following the creation of a Ministry for the Sea, the government has enacted a "Ministerial Meeting for the Sea", where the relevance of "offshore renewable electricity" was explicitly recognised and where an Inter-ministerial Working Group was set-up to address its future development. This working group, which includes participants from the relevant government departments and agencies and also representatives from science and industry, is expected to propose a model of development for the field. Moreover, the government document that creates the Working Group reinstates, to a great extent, the strategic approach that was adopted in the mid-2000s towards wave energy. It points out that the country has already developed considerable competences and some important assets in this field; and that, as it happened with other RETs, "offshore renewable electricity" can stimulate the development of a value chain supported by highly qualified labour and thus contribute to the development of competitive industries with an export orientation. This suggests a renewed interest in the field and may indicate the intention to act more decisively towards an acceleration of its development, through a broader systemic approach.

Table 2: Characteristics of policy mix in *system growth* and *system crisis* periods of ocean energies in Portugal

	Main transition periods in the development of the OE system in Portugal	
Elements of policy mix	**System growth & strategic focus**	**Political divestment & system crisis**
Strategy	Wave energy as an element of a broader strategy aiming at sustainable energy transition and development of sea economy. Goal: Profit from favourable conditions to gain a prime mover advantage, achieving international position in the emerging wave energy field; develop "industrial cluster" that combines new activities with rejuvenation of existing ones.	Major changes in priorities defined at country level: strategic focus on renewable energy disappears; support to their development is reduced. Strategy for wave energy abandoned. Political interest in new ocean technology (floating offshore wind) induces had-hoc support but no strategic approach. Later: ocean energies as part of Sea Strategy providing new strategic focus, but no specific strategy for the field (currently under development?)
Instrument mix	Systemic approach that is attuned to stage of development of the technology and goals to be achieved by its diffusion. Centered on support to experimental development: flexible pilot & demonstration infrastructure that can evolve to accept commercial installations; comprehensive set of regulatory measures that addresses key problems in a coordinated way; combined with demand side mechanisms and traditional R&D and innovation support. Missing: instruments to promote development of industrial cluster	Process of policy implementation does not match early strategic ambitions: delays in infrastructure installation and in aspects of regulatory framework; political disappointment due to system problems and strategy change due to financial crisis slows down and then halts policy implementation. Instrument mix never fully implemented. Replaced by fragmented legislation, reactive to individual project/promoter needs. Introduction of generic cluster policies and creation of Sea Cluster Platform has impact in field, raising awareness among existing sea-related industries and stimulating interaction with them.
Policy processes	Formulation of vision and identification of strategic opportunities/ challenges based on	Departure from previous systemic approach amplifies disappointment with results below (inflated) expectations,

	extensive consultation with stakeholders. Difficulties in implementation of more complex mechanisms and in coordinating between different government areas. Inflated expectations / pressure to achieve fast results (before full instrument mix is available) influence policy decisions and start bringing about changes in policy orientation.	reducing government commitment. After financial crisis sustainable energy transition recedes as major societal goal. But Sea Economy goal retains importance generating some political interest in ocean energy by the Sea government area. Growing intervention of other political levels: local authorities contribute to local embedment of new technologies, driving renewal of local (sea-related) industries and engaging local populations in transition governance. System actors' efforts to vision (re)building and strategy formulation in the context of two Roadmaps go largely ignored by policy-makers.

5 CONCLUSIONS. SYSTEMIC POLICIES FOR SYSTEM TRANSFORMATION: LESSONS LEARNED AND REMAINING CHALLENGES

5.1 FROM STRUCTURAL FAILURES TO SYSTEM INNOVATIONS AND TRANSFORMATIONS

Managing the development of new sustainable energy systems, based on a new generation of technologies with high potential, is a complex and multilayered process, as was demonstrated by the attempt to promote the diffusion of new ocean energy technologies and to build a new industry around them, presented in this study. Such complexity is inherent to three main issues, which are also the basic premises of this report. The first premise, addressed in section 2, is that there are major challenges that need to be tackled for a new (ocean energy) system to emerge and continue to develop. The most important challenges relate: to the very nature of sustainable transition process; to the complexity and immaturity of ocean energy technological solutions; to the institutional dimension of system development, where coordination between various actors, practices and structures is required, and new rules and modes of organization need to be introduced and accepted; and finally, to the fulfillment of the transformational potential of the emerging system regarding existing sea-related industries (often traditional or declining).

Section 2 also makes clear that those challenges are difficult to solve because the underlying problems are persistent and interrelated. The persistence of these problems may be explained by the fact that they are caused by processes and practices deeply rooted in societal structures and patterns of socio-economic-technological development. The literature refers to them as 'system weaknesses' or 'system structural failures' at various levels, namely at the level of actors, networks and institutions. Hence, their resolution calls for profound processes of change, involving both system innovation and transformation, which takes us to the second premise of this report. The case of ocean energies offers an interesting case in this context, as it allows examining *how sustainable innovation goals* - i.e. the construction of an ocean energy system based on new generation of renewable technologies that can contribute to a sustainable energy transition - *and structural change goals* – i.e. the expected contribution of an ocean energy industry to the revitalization of a declining ocean economy - *can be combined.*

Section 2 equally advocates that addressing these structural failures requires a new policy rationale that stimulates structural change and enables new system development. The basic idea that emerges from this section is that it is necessary to rethink current policy making and develop a new policy perspective that adopts a systemic, more integrated approach to innovation, aiming at establishing synergies between various elements of the innovation system and thus allowing system transformation. This is the third premise in our analysis, and it is in this context that the process of formulation and implementation of a systemic policy (including its ups and downs) is analyzed in this report (see Figure1).

A systemic policy approach requires a thorough identification of systemic problems and, accordingly, the formulation of a comprehensive and coherent policy mix to address them. This should encompass a set of policy instruments that reinforce each other and are able to address these systemic problems in an orchestrated way, targeting not only technological and economic conditions, but also wider issues such as institutional factors or actors' expectations and beliefs. How systemic policies can contribute to overcome ocean energy challenges and remove obstacles to the development and transformative diffusion of ocean energy technologies is briefly discussed in section 3.

The case of ocean energy development in Portugal, in the last two decades, illustrates some of the conditions (at the policy and system levels) that drive the formulation and the (sometimes tentative) implementation of systemic policy tools. Section 4 shows that the construction of a new system can be understood as the co-evolution between policy making processes and system development processes taking place at several levels (technological, economic, cultural, and institutional), which influence each other dynamics and co-determine a transition trajectory. Identification of complementarities between disparate (parts of) systems is a critical contribution of policy in this context. Systemic policies provide a set of tools able to reinforce these connections, to couple (or link) various system elements and, by doing this, to reduce system coordination failures, addressing them in an integrated manner and bringing about large-scale change.

Figure 1 depicts the main challenges to the development of an ocean energy system and the requirements they raise for policy. The systemic nature of such requirements demands policy changes in order to successfully address them and achieve effective system transformation, as will be exemplified through the discussion of roles played by the systemic policy instruments analyzed in this report.

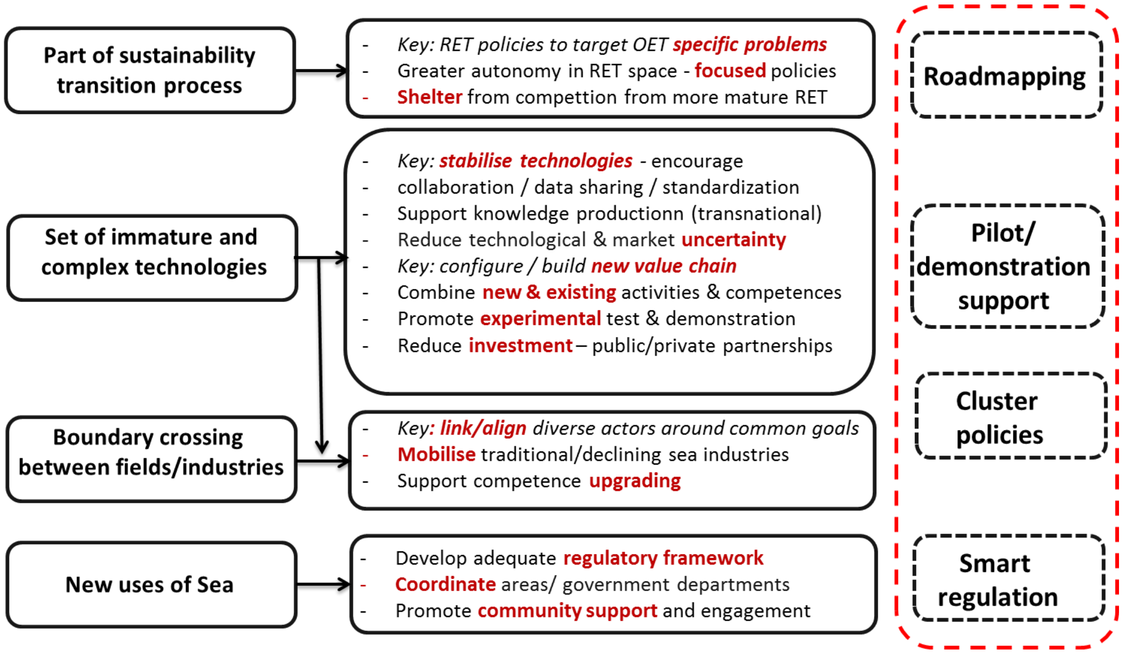

Figure 1: **Ocean energy system: challenges and policy requirements**

5.2 SYSTEMIC POLICIES FOR SYSTEM TRANSFORMATION: LESSONS LEARNED AND REMAINING CHALLENGES

The following sections summarize the key findings of this case study concerning the contribution of system innovation policies and, more specifically, a number of systemic policy tools - pilot & demonstration, cluster policies, roadmapping, smart regulation - to the processes of system innovation and transformation, as discussed in section 4. We start by highlighting key processes underlying the formulation and implementation of systemic policies. We then focus on the individual policy instruments and examine which appeared to be their impact on the system, individually and through their interactions (or lack of), as well as which were the **critical points** in terms of their application. Critical points are defined as the processes/conditions/particular designs of systemic policies that are central, given their capacity to make connections and establish relationships between disparate parts of the innovation system, e.g. technologies, actors, policies. For a summary see Table 3.

5.2.1 Key conditions for systemic policies formulation and implementation

As discussed in section 4, the process of development of an ocean energy system in Portugal was very much associated to the attempt to build a coherent and comprehensive policy mix for this area. The systemic nature of this policy mix was reflected not only on a combination of different types of instruments (including systemic instruments), but also on its expected capacity to create new opportunities and connections in the emerging ocean energy system, which would not have developed spontaneously and that appeared as critical to address a broad range of systemic failures.

Here we refer, first of all, to the definition of a clear vision regarding the long-term objectives to be achieved (that were grounded on broader country development goals), which provided guidance and also signaled government commitment. We also refer to their translation into an integrated set of policy instruments, with particular relevance to the novel combination of a broad range pilot & demonstration facility with a "smart" regulatory framework for the production of electricity from waves and with demand side incentives; as well as the introduction of wave energy cluster logics and its association to the sea economy revitalization. These policies were formulated at a moment when the system was starting to gain some dynamics and they appear to have been adequate to encourage and sustain actors' initiative. In fact, the analysis has also shown that the sole **announcement of the intention to launch some of these systemic policies** had an impact on **system growth,** effectively boosting it during the "strategic focus period".

A salient aspects of this policy process was the adoption of a systemic view on policy intervention, including the attempt to achieve a match between the vision for wave energy field and broader policy goals, the willingness to consult with system level actors, the effort to go beyond established boundaries (e.g. energy and sea) and link between previously unconnected areas/activities/competences. This configures an effective change in the role of government.

However, the process of **implementation of systemic policies did not match the strategic ambitions.** It proved to be a complex process facing a number of problems: some of them were inherent to the system behavior (e.g. expectations on system growth that outpace system capacity to fulfil them leading to hype and disappointment); others were specific to individual instruments, whose complexity may create difficulties in effective implementation; still others were related to the nature of the policy process.

Regarding the latter, the **growing policy influence on the development of the field** – reflected first in attractive political narratives and later in government betting on fast results from one major "flag project" – though momentarily increasing field legitimacy, also left the system vulnerable to project failure (always a possible outcome, given the intrinsic uncertainty of the innovation process). In fact, such failure resulted in a drastic change of government attitude towards wave energy, which would subsequently affect its behaviour towards the field, thus exacerbating its difficulties, instead of contributing to surmount them. The fact that this occurred before the instrument mix devised was fully implemented was particularly detrimental, because it delayed (or even stopped) such implementation.

Besides difficulties in the actual **implementation of the mechanisms devised**, it is also relevant to refer the **absence,** in the instrument mix, of some **systemic policy instruments relevant to achieve the policy goals.** This is the case of mechanisms aiming to promote the development of industrial competences and the creation of a "wave energy cluster". It is nevertheless possible that, given the still immature stage of the technology, these types of instruments were not regarded as indispensable at that stage. Indeed, following from the previous – successful – experience of wind energy, they might be planed for a later stage, when business opportunities started to emerge for new industrial activities and, particularly, for the re-orientation of existing ones. But system decline that occurred in the "political divestment" period prevented the creation of such conditions. However, at a later stage the presence of broader sea-level clustering initiatives emerged as relevant to start **creating connections with other sea-related industries** which may, in the future, contribute to fulfil the ocean energy transformative potential.

Considering the above, it is possible to conclude that, while the system positive reaction to policy announcement and its fast adherence to the mechanisms that were implemented suggest that the policy mix devised had an effective potential to promote system development, it is not possible to fully assess its actual impact, due to its incomplete implementation and the subsequent difficulties, largely of external origin. However, those events also offer some insights into the problems faced in the process of implementation of systemic policies, which can be internal to policy making process or result from unexpected outcomes or external shocks.

In particular, our case shows how economic conditions can lead to changes in the political attitude regarding sustainable transition processes. This can be particularly problematic for immature technologies, which though considered as a part of the ongoing transition process - thus still benefiting from broader transition-oriented policies – become particularly vulnerable in turbulent times of economic instability. In the case of ocean energies this resulted in withdrawal of government support, reinforcing the system crisis. The broader lesson here is that a country's **innovation policy mix** is directly **reliant on its economic policy**: one cannot be sustained without the active and stable support from the other.

5.2.2 System transformation goal: to what extent the processes conducted contributed to it

Regarding the system transformation goal, i.e. the contribution of ocean energies to the revitalisation of existing industries, the policy instruments introduced or announced have nevertheless enabled some first steps in that direction, in particular through the encouragement of experimental activities. The introduction of legislation that addressed some more pertinent regulatory problems and the implementation of mechanisms that provided some support to test and demonstration activities (despite the absence of the central mechanism devised at this level), as well as the presence of demand side incentives, enabled the conduction of real sea experimental projects, which provided the setting for some early integration of activities from different sectors. In particular they encouraged technology developers to bring-in actors from sea-related and other established sectors, motivated their engagement and promoted some learning processes. This had a positive impact in terms of early system construction and also contributed to confirm ocean energy transformative potential. However, since these processes were largely had-hoc, associated with the initiative of technology promoters, eventual learning processes remained individual or confined to a small number of participants. Moreover, the small number of projects that ended-up being pursued did not permit these processes to be sustained.

The more recent introduction of cluster oriented policies, in the broader "sea-economy" context, was important since it contributed to raise the awareness of opportunities offered by ocean energies among actors from other sea-related sectors. However, they are still mostly concerned with networking, i.e. promoting connections, whereas their translation into actual industrial development will require other types of mechanisms that encourage business investment and new competence creation. Moreover, the only organised attempt to assess the situation/potential/needs in what concerns the development of a domestic value chain to support the ocean energy field - the Roadmaps - was from the initiative of actors, with limited intervention from policy makers and their policy proposals had no real follow-up.

Thus, while policy strategies consistently associate ocean energy technologies to the development of the Sea Economy through their impact upon existing industries, the innovation support framework at this level remains fragmented and with several gaps. Some advances that have nevertheless been achieved at this level were mostly driven by the needs of existing projects and the perseverance of some system actors.

5.2.3 Opportunities, challenges and critical points for systemic policy implementation

- **Pilot & demonstration support and experimentation**

As discussed in section 3, experimentation is critical in emerging technologies, not only to prove technology viability, increase system performance and decrease costs, but also to achieve more systemic goals. These include establishing new connections between so far unrelated actors and promoting the associated learning processes, setting a "blueprint" for a new industrial value chain, identifying and addressing new regulatory issues and environmental problems and achieving community support and engagement with the new technological solutions. At least some of these effects were anticipated in the policy documents that prepared and proposed the creation of a shared test and demonstration facility – the Pilot Zone for Wave Energy. But the continuous delays in its implementation do not permit us to assess whether and how such effects would have occurred in this case, either individually for the different experimental projects that might have been installed, or for the system as a whole, through the synergies and learning processes that might have been achieved.

However, the conception of this facility and the associated regulatory framework call our attention to an important aspect of the policy making exercise that underlined the formulation of this particular instrument mix. At the core of this exercise there appeared to be recognition of the need to **make connections** (at system level); and experimental development was a central piece in this process, since it enabled the link between technological innovation and wider structural change. This approach was grounded on the definition of broader country level strategies, and on the positioning of renewable energies, in particular wave energy, as an element to achieve structural transformation; as well as on an in-depth assessment (in consultation with system actors) of the systemic opportunities and problems to be faced when pursuing this route. Indeed, the historical analysis of this period (sections 4.3.2 and 4.3.3) suggests that making connections was central to the dynamics of the ocean energy system in Portugal

Thus, a central function of the instrument mix conceived to support experimental development would have been making connections at system level, thus addressing system failures. This was expected to be achieved through: i) a **novel combination** of **a pilot & demonstration facility** and a **"smart" regulatory framework**, and their **interdependence with** more traditional **R&D instruments** and less traditional **demand side incentives** - which would encourage technology developers to pursue with their innovations beyond the early stages and, by reducing risks, also motivate external investors; ii) the pilot & demonstration facility potential to pr**ovide the setting for the staged development of a new (wave energy) value chain**, including the attraction and engagement of **actors from sea related industries**; iii) the collaboration between **different government areas**; and finally iv) the **learning processes** these processes would entail. The pilot & demonstration facility can be regarded as a physical space able to support experimentation with the above mentioned issues, thus enabling learning at various levels - technology, industry, policy, civil society - and also contributing, at a cognitive level, to the formation of actors' visions and expectations.

Continuous delays in the implementation of the Pilot Zone facility did not permit to create the conditions for these effects to fully unfold, while the financial crisis and subsequent government divestment from the field increased the challenges faced by experimental activities. At the policy level this corresponded to a lost opportunity, since the novelty of the approach eroded over time, thus removing the competitive advantage it offered the country. It also prevented policy learning processes that could lead to improvement of instruments and/or their adjustment to the nature of the system and its evolution. At the system level, this meant a great reduction in the number of experimental projects (which also reduced variety, an important element in experimentation), and for the ones that were conducted, a more limited scale and often no continuity. In addition, while some of the above mentioned effects still occurred and learning processes still took place, their scope and overall impacts in the system were possibly lower than if they had been conducted in the context of a shared facility and under public scrutiny.

An example of the potential systemic impact of experimental activities can be seen in the case of the only wave energy project that resisted to the system crisis and policy divestment. As pointed out in section 4.4.3, the permanence of this project in Portugal and its actual capacity to achieve some of the expected systemic objectives in a difficult period, is associated to the **role of the local/regional level policy.** The local authority was aware of the importance of stimulating relationships, at local level, between that specific technology and other activities related to the sea, and revealed ability to promoting dialogue with local actors and thus engaging them in transition governance. In fact, here we see how mutual reinforcement of positive results of technology experiments and changes in structure (e.g. the changing role of the state, here expressed in the support from local authorities, changes in regulations and market conditions, and associated changes in practices) may lead to broader learning, manifested as a shared problem understanding among various actors, which is a necessary condition for collective action.

Based on our results, we conclude that experimenting with emerging technologies requires **balance between stability and flexibility**. In other words, pilot & demonstration facilities should be structured as infrastructures that allow gradual co-development of specific technological designs and a new socio-economic structure, through coherent and dedicated policy support. Such support should be based on policy instruments and governance mechanisms that are both robust enough to deal with the complexity of technology, and flexible enough to endorse uncertainty and include possibility of failing and learning from failures. Policy learning should thus be part of these experimental process and policy changes should reflect the lessons learnt from these processes, in what concerns both the design of policy instruments (including their interdependence) and their capacity to achieve the desired effects.

In this context, when aiming at structural transformation, experimental support programmes should **go beyond technological objectives** and projects should also be evaluated in terms of **the degree of contribution to (sustainable) transformation goals** they are able to induce**.** In addition they should also create conditions for the learning achieved at the experimental project level to be **collected, aggregated and disseminated across the system**, as well as **translated into lessons** on necessary policy changes.

- **Cluster Policy**

The idea of a "wave cluster" and its role as a driver of industry transformation was, from the very early stages, an **essential element of a vision** for wave energy development and remained a **persistent policy goal** of ocean energy legislation. It is possible to argue, that one major value of the cluster approach relates to its potential to **legitimize technological innovation, making it relevant (and attractive) for policy makers**. System actors have early framed the wave cluster as an **opportunity that would** emerge from the development of the new technology, exploring the relationship between the wave cluster and a broader country strategic goal – the creation of a Sea-based economy - to promote the development of ocean energy technologies. In the period of system growth, the idea of a “wave cluster” was found to directly **influence policy objectives**, underlying a political narrative centered on country leadership in renewables, aiming at attracting actors from both inside and outside the system, but it also led to a greater policy influence on the development of the wave energy field. Our case also reveals that the cluster logics can create a space for **policy coordination** (e.g. between different areas such as energy and sea), that facilitates interaction/collaboration between multiple groups of actors and alignment of their diverse activities/skills and competences.

However, in our case, there was also a continued **absence of specific ‘cluster’ measures/mechanisms,** which only recently started being filled (albeit indirectly**)** through the introduction of a “Sea Cluster” platform that encompassed ocean energies. This was an important policy gap, since such measures would have been a powerful instrument to address system coordination failures and to reach the proposed policy goals, namely: i) to provide an industrial base that could support experimental projects; ii) to uphold orientation of existing industries towards the new field; iii) to start creating synergies with sectors with competences pertinent for the ocean energy field (e.g. underwater robotics, advanced materials, oils & gas logistics) as well as with other sea-related sectors (e.g. aquaculture) in the scope of ocean economy. While the emergent nature of the system might have been behind the absence of mechanisms targeting actual industry development (as actual business opportunities were limited), the early introduction of awareness raising and network development mechanisms, such as the ones later present in the Sea Cluster platform, might have been beneficial. Moreover, as experimental projects started to be installed, such mechanisms might have encouraged more companies in complementary fields to engage in the new field and/or to invest in competence development for that purpose; and technology promoters to resort more extensively to local companies.

Section 4.3.2 exemplifies the importance of **experimental activities** and thus, of the **pilot/demonstration facility** in this context, showing that it would have been a crucial element for the formation of the cluster. This interdependency between instruments is positive per se, but may prove problematic as it implies that instruments operability depends on their combined implementation. We see this from delays with Pilot Zone installation that may have precluded an increase in the number and variety of experimental activities. Given the scarcity of opportunities (which was further aggravated by system level problems and by the impact of the financial crisis on investor behaviour) the role of experimental projects as setting to start creating a cluster environment was limited: besides scientists and a small set of local technology developers, there was reduced participation of other actors, namely national companies in complementary industries, in the few projects that did proceed.

However, more recent developments associated with the launch of floating offshore wind projects and the continuity of the few surviving wave energy projects suggest that, even with the sole support of a fragmented set of mechanisms (supplemented with European funding), experimental activities are nevertheless playing some functions that are important for cluster development and more generally system building. A growing number of actors from existing sectors along the emerging value chain have now been involved in these projects (some in more than one), gaining some experience with the technologies; a few of them have now invested in the development of new competences; actors from technology intensive and traditional companies may have learnt to work together. In addition, some technology promoters have gained experience in the coordination of this type of complex projects and have now built a “portfolio” of suppliers; and even if some of these suppliers are foreign, given the absence of local ones or promoter choices (who are sometimes foreign themselves), local companies are also learning at both the technical and the business levels, from exposure to them. This can be described as a very incipient 'embryo' of the (yet to come) ocean energy cluster. But it is exactly at this stage that purposive and integrated cluster policies become pertinent, to strengthen these efforts and boost further development.

As pointed out above, the introduction of cluster policies that supported the creation of a Sea Cluster platform, with ocean energy as one component, is an important step. This instrument contributed to raise the awareness of opportunities offered by ocean energies among actors from other sea-related sectors and permitted some interaction between them and ocean energy actors, who profited from the networking opportunities provided. But it is also necessary to translate these into actual engagement with the new field, which will require human and capital investments and thus demand different types of incentives. On the other hand, it is necessary to gain a better understanding of the current potential and conditions for cluster development around ocean energies, since the situation changed significantly since the mid-2000s. That is, a **new system diagnostic** is a requisite. Efforts at this level were conducted in the context of two Roadmapping exercises led by system actors in the early 2010s. But this diagnostic requirement only now appears to be addressed by the government, as part of a renewed interest in ocean energies that led to the recent creation of Working Party to conceive a development model for the field.

- **Roadmaps**

In section 3, roadmaps are described as an important instrument for the articulation of shared visions and expectations regarding the future development of a technology, providing guidance and contributing to achieve actors' commitment and alignment. Hence, they refer to the **cognitive side of the process and can** provide a setting to **translate lessons** learned at the level of experimental developments into necessary policy and system change, or the other way around. The two roadmaps for ocean energy that were produced in Portugal by initiative of system actors, illustrate an attempt at the application of a systemic approach to system development, since they had a broad scope encompassing technology situation/perspectives/non-technological opportunities/obstacles and putting particular emphasis on value chain development.

Furthermore, as explained in sections 3 and 4, they had an added value, in terms of "**timing"** – they were produced at a period of system crisis and political divestment, when the systemic policy approach had been abandoned. Hence, they were **designed to contribute towards system recovery and reconfiguration**, rebuilding of a vision for ocean energy development and seeking actors' re-engagement and political attention. In fact, this was the only organised attempt to assess the situation of existing industry, as well as its potential and needs in what concerns the development of a domestic value chain to support the ocean energy field. And yet, precisely because of this timing (turbulent times of economic instability), their effectiveness appeared to be low, at least at the political level. In fact there was no government involvement and no follow up to the proposals made in terms of policy formulation and government intervention. This limited their potential impact.

This case suggests that, while Roadmaps do not necessarily need to emerge from government initiative, their role as policy instruments is highly contingent on the policy makers' attitude towards their production and/or their subsequent use. Government's decisive involvement in their production is important because it can increase their credibility, as well as bring about the participation from a greater variety of actors and a broader debate (e.g. precluding attempts at capture by powerful interest groups). But even if the government is only involved as another stakeholder, the willingness to discuss the results and eventually take them into account when formulating policies is an important step to turn the Roadmapping exercise into a relevant form of policy intelligence. In that sense the efforts conducted at the outset of the "strategic focus period" - which combined the government willingness to consult with system actors with the latter in-depth assessment of system conditions, opportunities and problems - despite their "embryonic" nature, ended-up being more effective in policy terms than the recent Roadmapping exercise. Not because the Roadmaps were not thoroughly produced and widely participated (at least among the actors more related to the system), but because the government – for a variety of reasons - was not sensible to their results, including the explicit policy proposals they put forward.

Thus these Roadmaps can be mostly described as an example of positive efforts at system level. Even if confronting some difficulties in mobilizing actors (especially external ones) at a time of system decline, the Roadmapping process has nevertheless acted as a factor of actor alignment around a new vision for the field – centered on the systemic idea of value chain development - and have provided a guide for coordination and action. This confirms its role as a valuable tool for system development (particularly if it goes on being updated and improved). It also makes it a tool that can still be used by policy makers as basis for interaction with system stakeholders in policy formulation: indeed recent developments at government level suggest that such interaction is regaining importance in this field.

- **Smart regulation**

Our case study provides an interesting account on how the development of a new system, based on emerging technologies, raises new problems that involve different spheres of economic and social life and thus requires addressing a set of new regulatory questions. In this case, this included issues related with maritime spatial planning, defining a specific regulatory framework that removed critical obstacles (e.g. consenting and licensing procedures), addressing environmental issues, and motivating coastal communities to accept and engage with the new activity. In addition ocean energies are also encompassed by the more generic regulatory framework introduced for renewable energy production and changes at that level can have an important impact in the emerging system.

The case has shown the importance of engaging in smart regulation, that is defining a comprehensive regulatory framework that addresses key problems and, at the same time, aims at simplifying procedures, producing legislation that is accessible and easily understood. It also uncovered the interdependence between regulatory tools and other systemic policy tools - e.g. pilot & demonstration; cluster development mechanisms – which are particularly evident in the case of emerging complex systems. Such interdependence provides both opportunity and challenges when it comes to the implementation process. Opportunity, because the conduction of experimental activities and the need for interaction between different sectors enable learning that can be translated into the regulatory framework, permitting adjustments or improvement. For example, experience and lessons from various real sea projects provided insights for the simplification of the licensing process, which is identified as one of the major non-technical barriers to the development of ocean energies. But interdependence also creates challenges, because it implies that operability may require **combined implementation, in which case delays or problems at one level may** be problematic for the whole system. For example delays in the implementation of the experimental facility led to a halt on the implementation of an integrated regulatory framework, resulting into regulatory fragmentation and gaps.

The capacity to formulate and implement "smart regulation" that effectively supports the development of an ocean energy system raises an additional challenge at the policy level. As was already pointed out, the activities in the ocean energy field encompass different areas, which are object of **different strategies/policies, implemented by different entities.** This demands great **policy coordination**. Such coordination needs to be achieved between policies, as well as between government departments and administrative agencies implementing them, in particular, coordination between the Energy and Sea areas. Not only this coordination has been limited so far, but the case study has also show that, because of its emerging nature, ocean energy tends to be relatively marginal in these well-established government areas. Thus, the field may need to be singled-out in order to more clearly identify its problems, opportunities and requirements and to define needed actions, as well as to figure out how to integrate it with the activities taking place in the two broader areas, to which it can simultaneous contribute and benefit from.

Finally, the relationship between ocean energies and other RETs and the resulting regulatory overlaps are also a relevant issue. Ocean energies are one element in the process of sustainable energy transition and, from a transition policy perspective, it is important to achieve a balance between the various renewable energy sources (ocean, onshore wind, sun, hydro, geothermal, etc.) that have different characteristics and are at different stages of development. As pointed out in section 2, ocean energy technologies have a number of particularities that differentiate them from other RETs that have now achieved greater diffusion in Portugal – e.g. the greater uncertainty created at various levels by their immaturity and the regulatory difficulties resulting from their sea location. Since ocean energies continue being regarded as strategic in country development policies, these particularities need to be acknowledged by RET strategies and policies and may require specific instruments that (temporary) shelter them from competition from more mature RETs.

Table 3: Opportunities, challenges and critical points for systemic policies application

SYSTEMIC POLICIES	OPPORTUNITIES	CHALLENGES	CRITICAL POINTS
PILOT & DEMONSTRATION SUPPORT and EXPERIMENTAL ACTIVITIES	Dedicated infrastructures that enable **connections** - at system level - between technological innovation and structural change (e.g. change in practices, market conditions, policy adaptation). Setting where **technology and policy** can be **tested and developed,** contributing to **learning** at various levels. Setting for the **staged development** of a new **industrial value chain**: interdependence with cluster logics. Setting that may bring about **dialogue** with the wider **public,** supporting its **involvement in transition governance.** **Learning** as part of experimentation: technology learning, 'meta-learning', broader social learning.	**Delays** in implementation of demonstration facility **decrease actors' expectations and interest.** **High costs,** especially problematic in time of economic crisis. Absence of **shared facilities limits opportunities for synergies** between (small number of) individual experimental projects and reduces '**meta-learning'.** Limited **motivation of sea-related sectors**-limited development of new competences at that level: overall impacts on the system lower than expected. Need for **coordination between different governmental areas**; difficult to achieve.	* **Achieve balance between stability** (robust and dedicated policy support) **and flexibility** (policy that allow experimentation and failure, including learning from failures). * **Explore relationships between experiments and policy change** with focus on **policy learning** - **translation of lessons** learned from experimental projects into lessons on necessary policy changes or vice versa. * **Assess experimental projects** not only in technological terms but also **in terms of** the degree of **structural change they are able to induce.** * **Guarantee continuity of political commitment** to enable co-development between specific technological designs and socio-economic structures. * **Stimulate Involvement/ support of local and regional authorities** (important agents of change).
CLUSTER POLICIES	Idea of 'cluster' as a **driver of industry transformation.** Essential **element of vision** for	**Absence of** cluster oriented **measures reduces capacity to**	* **Importance of experimental activities:** crucial element for the formation of cluster (should also

	system development and **persistence as policy goal.** Relevance of 'cluster' mechanisms **to achieve policy goals of creating an industrial base** and **enable synergies** with other industries. Potential to **match** with and/ or **influence other policy objectives.** Potential to **legitimize innovation.** Space for **policy coordination.** Creation of collective organizations that contribute to raise awareness and develop networks. **High interdependence with other systemic policies.**	**address system failures** and to achieve policy goal of **creating an industrial base.** **Lack of critical mass of actors** hinders value chain development; while **lack of new business stimulation** prevents new actor entry. High **interdependence with other policies –** implies that its operability depends on **combined implementation.**	be funded as such). ***Define and implement specific cluster mechanisms** to address system coordination failures and reach policy goals, namely to: i) stimulate industrial base that sustains experimental projects; ii) uphold **orientation of existing industries** towards the new field iii) achieve **synergies between clusters** (e.g. sea-related). * Support **human and capital investment**s for development of new system related competences. * Need for **system diagnostic** and evaluation of national industry potential and gaps and international competition.
ROADMAPS	Opportunity to **formulate a new vision** for the field and **align actors around** it. **Systemic approach:** provide system diagnostic and offer guidance for potential development, combining technological and industrial development objectives, and addressing economic, social and political conditions. **"Bottom-up" approach** (stakeholders' initiative): as strategy to uphold system recovery and reconfiguration and seek actors' re-engagement. **Can inform policy making** by providing policy recommendations and supporting policy lobbying.	**Lack of government endorsement**: neither **involvement** nor **follow-up** of policy proposals ('timing': financial crisis and political divestments) **Limited impact on policy making.** Difficulties in achieving **broader industry involvement** (besides system related actors).	* **Government involvement**: increase **credibility** of roadmaps (and may favor broader participation and debate). * **Role of roadmaps as policy instruments** is highly contingent on **policy makers' attitude towards their production and/or subsequent use**: willingness to discuss the results and take them into account when formulating policies. * **Better understand the factors influencing and constraining** the actual process of Roadmap production. * **Importance of consultation & interaction with stakeholders for policy formulation** – as shown by experience from early policy making in the field.
SMART REGULATION	**Coherent and comprehensive regulatory framework** that: i) addresses **key** systemic **problems;** ii) aims at **simplifying** procedures, producing legislation that is accessible and easily understood. **Interdependence with other systemic policies** – learning from experimental activities and translation of lessons into the regulatory framework, permitting adjustments or improvements.	**Interdependence with other systemic policies:** operability implies **combined implementation**. Coherence and completeness: gaps in framework may impact its overall effectiveness. Delays or problems at one level may **impact the whole system.** Capacity to formulate and implement 'smart regulation' **depends on policy coordination.**	* Need to adopt a **systemic view** in order to be able to **identify and address system development requirements** in a **coherent and coordinated** way. * 'Smart approach' should be extended to RET policies as a whole with a view to **achieve a balance between the various renewable energy sources** in the scope of sustainability transition process. In this context the **specificities of emerging ocean energy** technologies should be addressed through specific RET policies that **support them** while (**temporarily) sheltering** them from other RET competition.

5.2.4 System transformation and policy instruments: Looking forward

The case of the development of an ocean energy system in Portugal is an interesting reminder of the need for the articulation of system and policies, particularly so in addressing the promotion of system transformation. While the specific case study of ocean energy in Portugal may reflect certain particular local conditions, the attempt at system transformation it reflects encompasses challenges that often characterize the general dynamics of sustainability transition and system transformation processes. These include not just the dimensions of the complexity of technological development but, also the reconfiguration across boundaries, in terms of heterogeneous fields and industries, leading to new (or recombined) systems, actors and institutions.

Systemic policies must thus support the development of the innovation processes, enable new connections, create the conditions for experimentation and the emergence of the new system configuration and promote the new uses which are central to the system transformation process. The analysis of the set of instruments which were here identified highlights how these can have an important role in the transformation process. Instruments such as roadmapping, demonstration projects, cluster policies or smart regulation, all contribute to enable new connections, at different stages of the innovation process, and to bring together different actors. The analysis shows that the implementation of the policy-mix needs to reflect the system level conditions, not in a linear but rather in a systemic approach. In the ocean energy system analysed here, it is clear that different stages of evolution required different policy solutions. It is precisely in the coordinated approach to the implementation of the policy-mix, reflecting the interdependence of instruments and system dynamics that lays the effectiveness of the implementation of systemic policies.

Policies can have an important role in nurturing transition and transformation by supporting experimentation, a common vision and cross-boundary linkages, and they can contribute to bring together new and old actors, and competences, contributing to reconfigure uses. But it is also clear that they need not substitute for the role of innovators and users in defining the conditions of success. The success in system transformation needs to follow from the co-evolution of the policy-mix and system dynamics and how this embraces conditions for experimentation, and for opening up new uses, actors and vision towards a sustainable innovation transition process.