nanoBasque

Roadmap for the application of micro/nanotechnology to marine energy

GRUPO spri

EUSKO JAURLARITZA
GOBIERNO VASCO

EKONOMIAREN GARAPEN ETA LEHIAKORTASUN SAILA

DEPARTAMENTO DE DESARROLLO ECONÓMICO Y COMPETITIVIDAD

Objectives of the document

- To promote development of the nanoBasque strategy and make greater micro/nanotechnology contribution to energy
- To develop a roadmap on the application of micro/nanotechnologies to the technological development of marine energy (offshore wind energy and wave energy)…
- … thus making it possible to foster the development of capacities and projects in the Basque Autonomous Community in the field…
- … and to understand the present position and future opportunities of the above as regards the development of Basque industry

1 Introduction

2 Methodology

3 Micro/nano roadmap in offshore wind energy

4 Micro/nano perspective in wave energy

nanoBasque

1. **Introduction**
2. Methodology
3. Micro/nano roadmap in offshore wind energy
4. Micro/nano perspective in wave energy

Energy is one of the fields with greatest potential for the application of micro and nanotechnology, particularly in areas which, although still less mature today, are experiencing strong technological development

- The **nanoBasque strategy** places the focus on energy as a key area for the application of micro/nanotechnology
- Within the different energy segments of interest to the Basque Country, the general rule is that **micro/nanotechnology is much more likely to find its place in the emerging than the mature sectors**, given that cost criteria in the latter may imply a higher start-up barrier
- **Marine energy and energy storage** are priority emerging areas in the **energiBasque strategy**; they have important needs in the field of technology development
- The result of the roadmap is the coming together and generation of symbiotic relations between the nanoBasque and energiBasque strategies

Given the above, it has been decided to focus this exercise on the less mature energy areas prioritised at energiBasque; marine energy and energy storage

This document concentrates on the two major lines of marine energy: offshore wind energy and wave energy

Offshore wind energy

- Draws on onshore wind energy technology, which has been adapted and improved for its offshore use
- First commercial solutions in pioneer markets
- Very high market growth forecast in the medium-long term

Wave energy

- Developing technology (different alternatives continue to compete)
- Solutions at pilot plant level
- Market still to be developed

offshore

Micro/nanotechnology roadmap in offshore wind energy

Detailed analysis of offshore wind energy

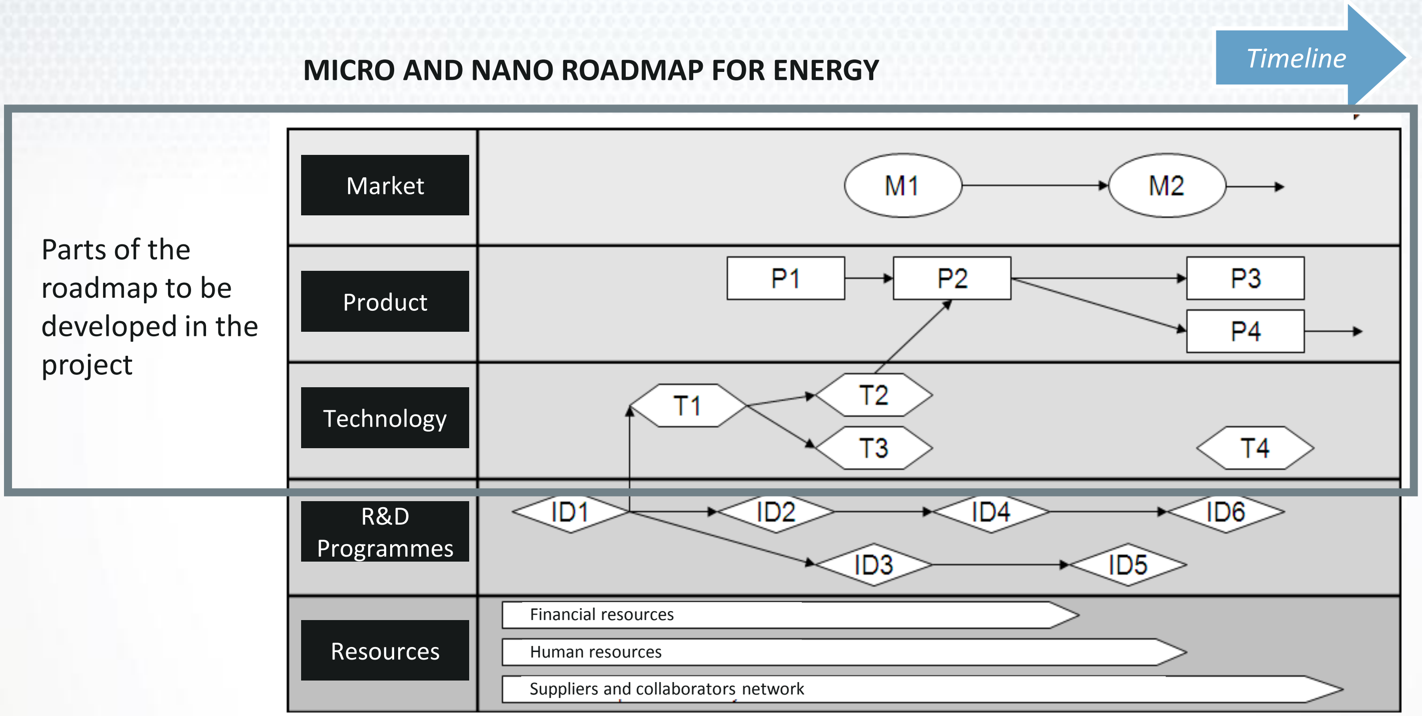
Shared elements and needs due to the nature of energy generating systems in offshore locations

Micro/nanotechnology perspective in wave energy

Extrapolation of the results of offshore wind energy to the field of wave energy

... which vary greatly as regards their technological and market maturity

The roadmap will provide understanding of offshore wind energy and wave energy as regards technology, product/market, and the relationship between them



Development of the different roadmap plans are intended to achieve understanding between languages and areas usually difficult to connect (market and technology)

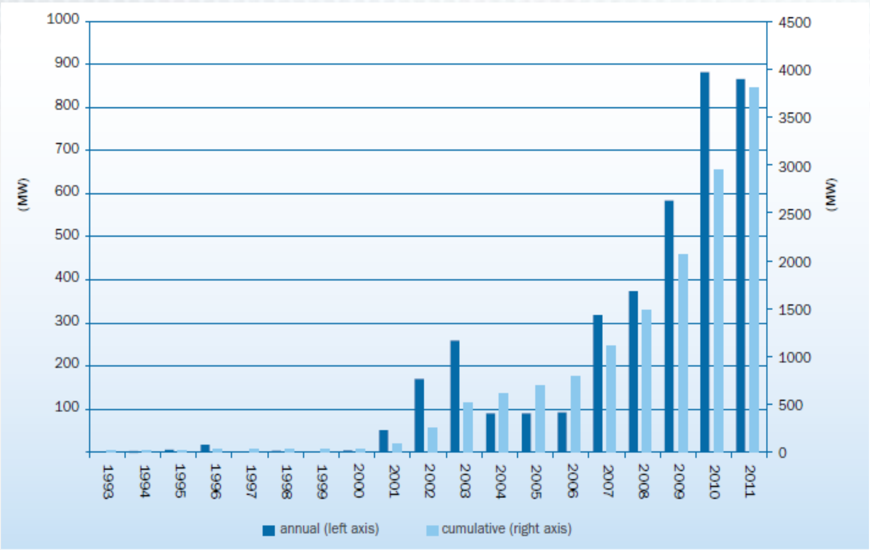
Offshore wind energy is currently one of the renewable energy segments with highest growth and future potential

Boosted by conditions of context that favour renewable energies in general	
Growth in energy demand	Growth in energy demand across the world and particularly in emerging countries
Rising cost of fossil fuels	Rise in the price of fossil fuels largely due to diminishing reserves
Optimum resource	Optimum resource in all respects; inexhaustible, clean and local, thereby favouring regional energy independence
Government backing	Government backing of both the technology and industrial aspects plays a decisive role and is the practical reason for its development

Has important advantages over onshore wind energy principally due to the potential of its location	
Larger available surface	Surface area available for large-scale projects , unaffected by the limitations of space on land
Higher wind speed	Wind speed is higher and tends to increase further out to sea
Greater effectiveness	Less turbulence leading to greater effectiveness of turbines as the load they have to bear is smaller
Lower environmental impact	Offshore wind farms have lower environmental impact

Offshore wind energy installed throughout the world is still low and concentrated almost exclusively in Europe...

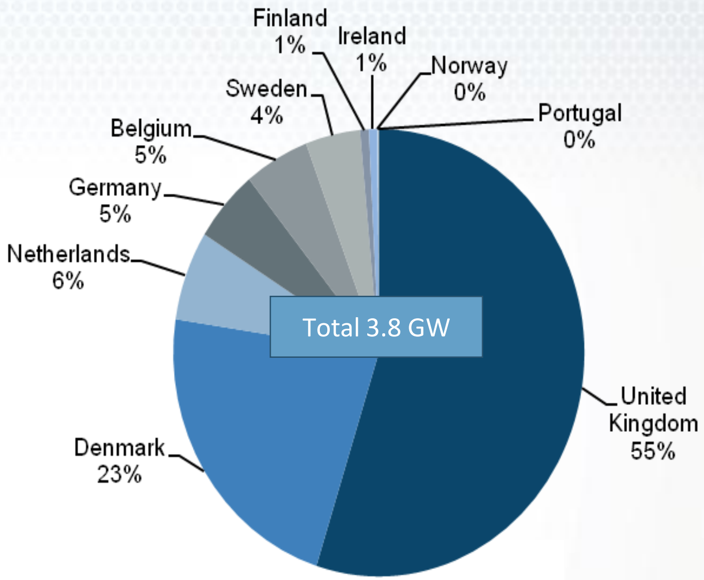
How offshore wind energy has changed in Europe



Source: European Wind Energy Association

- In 2011 there were 53 offshore wind farms in Europe representing total installed power of 3.8 GW
- 70% of capacity has been installed over the last four years (2008-2011)

Offshore wind energy capacity distribution installed by country (2011)



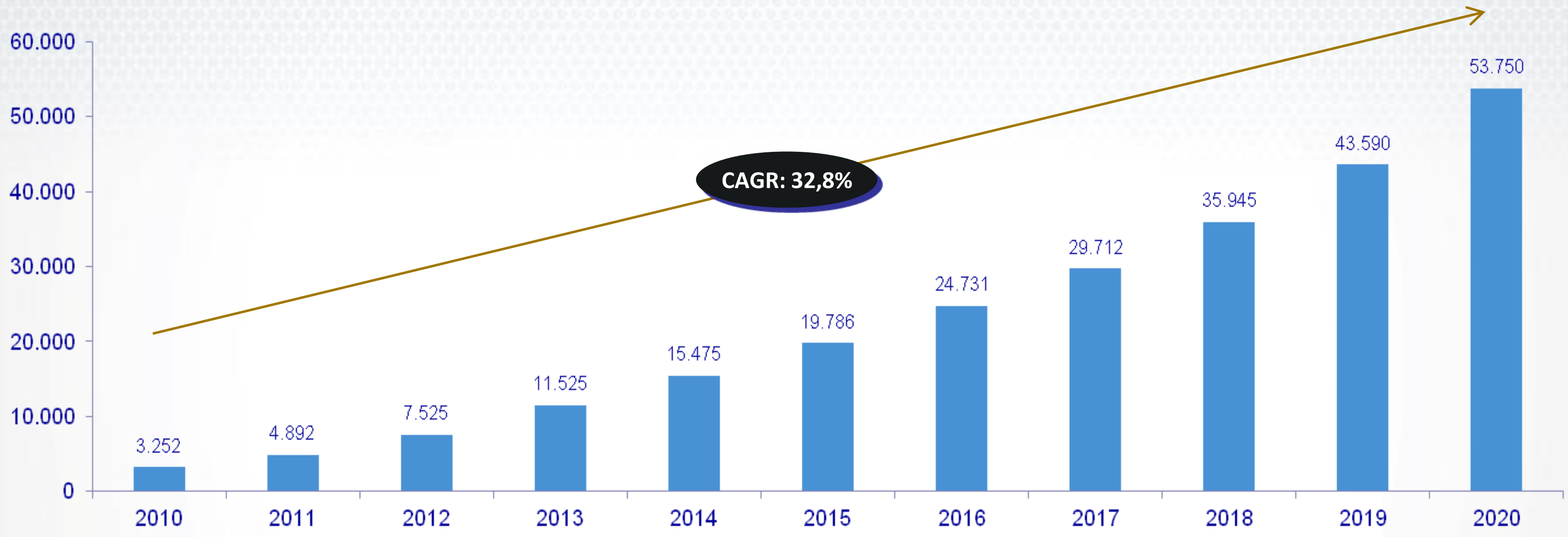
Source: European Wind Energy Association

- Initial development of offshore wind energy took place in northern European countries with barely any floor space and an extensive shallow marine continental platform.

... its development intensified over the last few years, boosted by Governments from some countries, particularly the United Kingdom

… but strong growth is expected over the next decade, with Europe firmly centre-stage…

Estimate of how the accumulated offshore wind energy capacity will change worldwide 2010 – 2020 (MW)

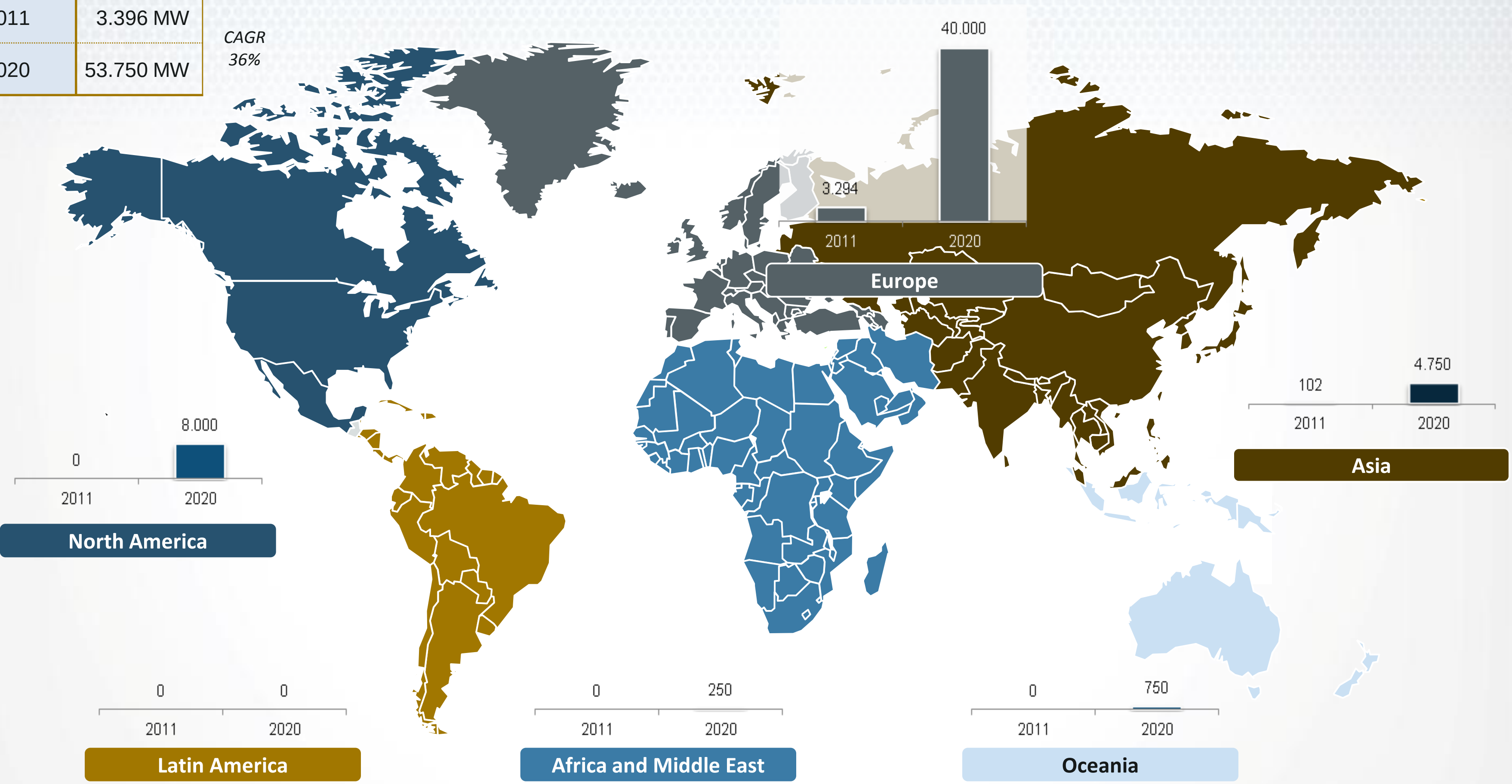


- Over the next decade, much greater growth is expected than seen to date, reaching 53 GW offshore installed by 2020, although it is true that some observers indicate more moderate short-term growth.
- In 2020, Europe will continue to be the main offshore wind energy market absorbing 75% of the energy installed throughout the world at this time, with the remaining 25% split between North America and Asia.

... and other smaller markets will appear, fundamentally in Asia and North America

Estimation of how accumulated offshore wind energy capacity will change throughout the world by geographic area (MW; 2011, 2020)

2011	3.396 MW
2020	53.750 MW

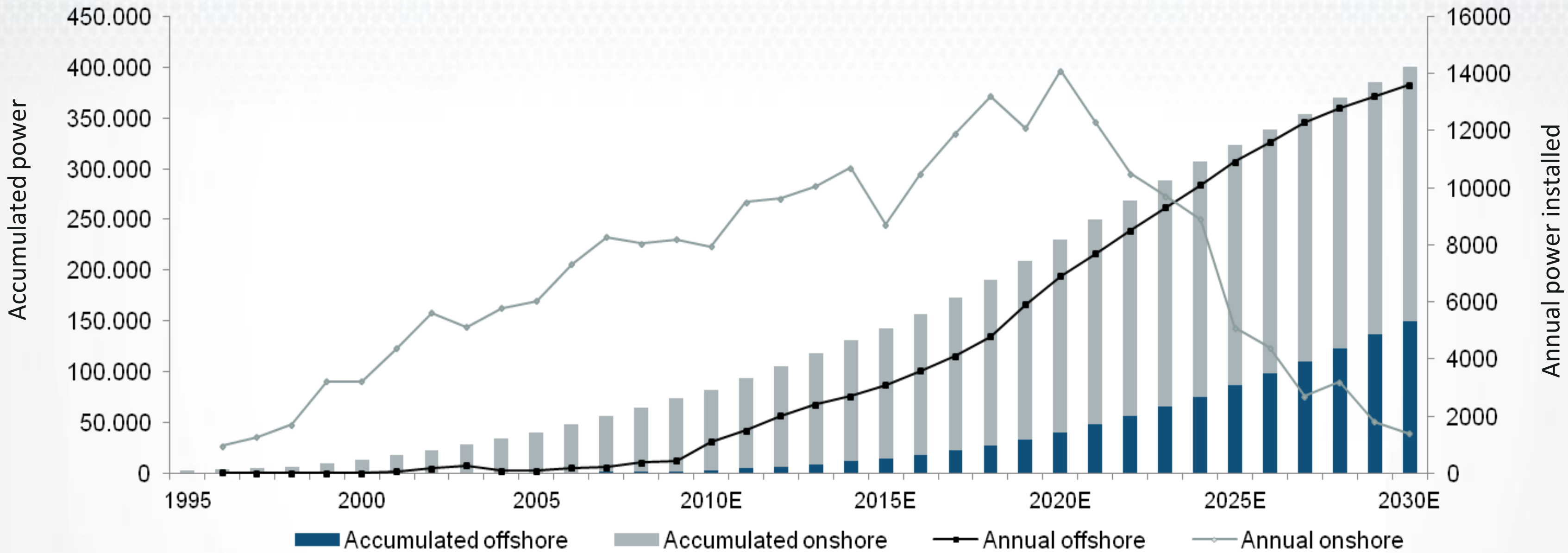


Source: "Wind in our sails" and "The European Offshore Wind Industry", EWEA

nanoBasque

From 2020 onwards, offshore wind energy will exceed market levels for onshore wind energy in Europe

Estimation of how accumulated offshore wind power capacity will change throughout the world 2010 - 2020 (MW)

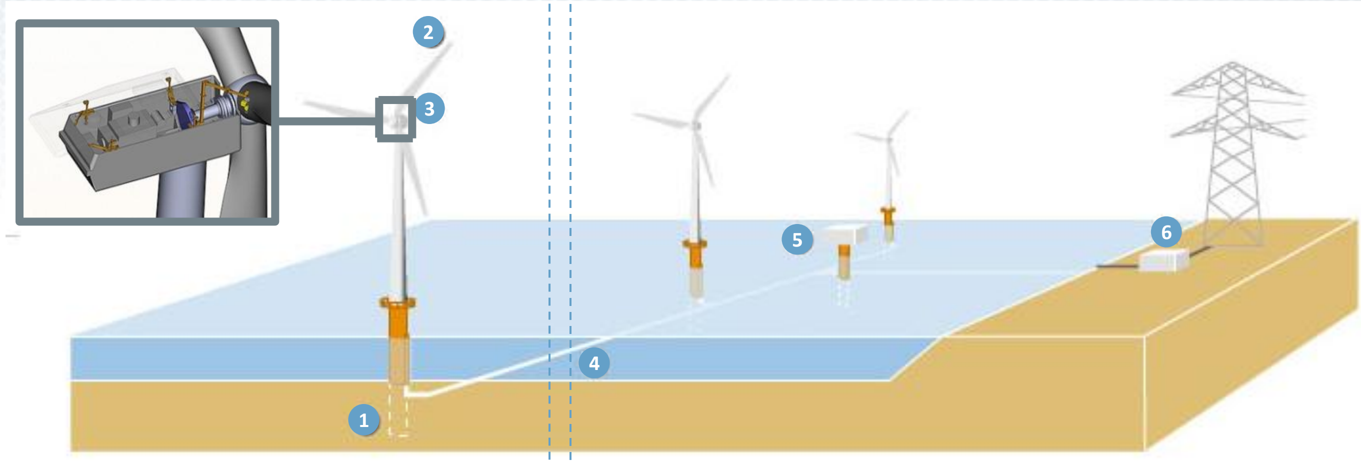


- In Europe forecasts point towards a clearly positive growth perspective for offshore wind energy energy up to 2030, whilst onshore wind energy will peak in terms of installed power in 2020, and then progressively fall. This will mean that annual offshore wind power installed exceeds the power installed onshore before 2025.
- It should be highlighted that forecasts for other world markets with less history in this field are very different, expecting installed onshore wind power energy to continue growing.

However, to meet these market expectations, offshore wind energy has to become more competitive...

Energy uptake system

Energy transmission system



1 Foundations and tower: wind turbines should hold a defined position so they are not fixed to the seabed. The tower is fitted on this foundation with just the right height to expose it to the selected wind force (the higher it stands, the stronger the wind).

2 Rotor: the force of the wind turns the aerodynamically-designed blades

3 Gondola: this is the part at the top of the tower to which the rotor is attached and inside which the parts are arranged to turn the mechanical energy received into electrical energy. The gondola can be directed towards the wind blowing over the tower

Underwater cable: the electricity generated is transmitted to land through a network of cables fitted along the seabed. 4

Offshore substation: In order to minimise losing electrical energy generated in the wind farm as it is transported to the coast, the voltage is raised in a substation located out at sea within the actual wind farm 5

Installing an onshore network connection that, depending on the existing network, might require a substation to be built. 6

... taking into account the greater complexity of the wind farm and its components compared to onshore wind energy

… the demands of its marine location must be met and returns guaranteed on infrastructures with much higher investment and operating costs than onshore wind energy…

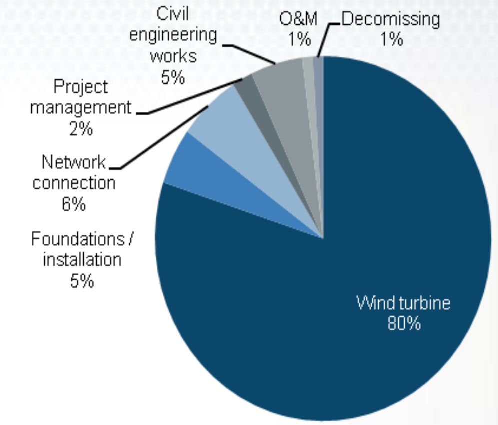
Requirements imposed by the marine environment

Reliable components	The components used must be proven as reliable to minimise the risk of breakdowns and a halt in the installations
Backup for critical components	Backup for critical components to ensure that the equipment will not stop operating in the event of problems
Monitoring	Monitoring, remote diagnostics, etc. to avoid unnecessary travel and guarantee that the equipment will continue to operate
Maintenance	Preventive, predictive and as little as possible: to increase time between maintenance work and reduce the time needed to do such work
Protection against corrosion	It is important to provide excellent protection against corrosion given the extreme conditions to which the components are subject

Volume and distribution of wind farm costs

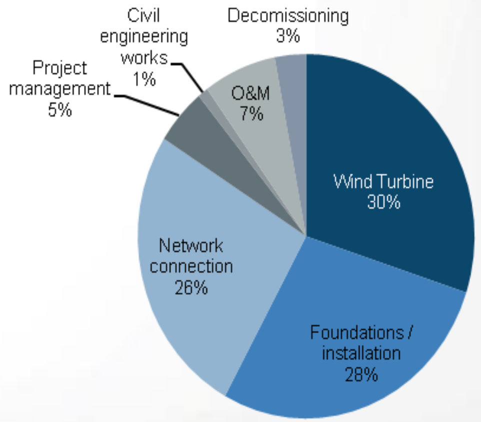
Onshore

Investment	€M1.3/ MW
Op. costs	1.2-1.5 €c/kWh



Offshore

Investment	€M2.7/MW
Op. costs	x5 / x6 compared to onshore

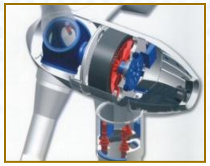


... turning it into an area undergoing great technological changes with challenges involving different levels and RTD needs...

Technological challenges of offshore wind energy

Turbines

Turbines with greater power through developing their generators, the use of new materials, etc.



Network connection

Network connection cables that allow long distance with limited losses

Foundations

Foundations that make it possible to locate wind farms at greater depths

Installation

Simpler and less expensive installation processes with help from new boats

Operation and Maintenance

Remote control and monitoring that avoids unnecessary trips to the wind farm

R&D needs

Design engineering

In order to develop new concepts and new structures capable of tackling new challenges. Developing simulation and CFD models plus control algorithms.

Microelectronics and electronics

Power electronics to develop new transmission systems (HVDC). Microelectronics to monitor the basic control parameters using sensors.

Material technology

Developing new materials, coatings and lubricants to extend the wind farm's useful lifespan. Applying methods and processes used in other fields, etc.

Tele-communications

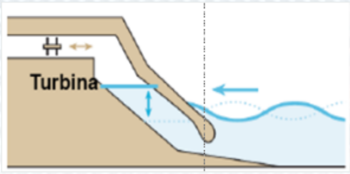
Advanced sensors, satellite control, to optimise its control, operation and maintenance.

... where micro/nano technology can potentially contribute

Different technological alternatives are currently being developed and tested in the field of wave energy, with no obvious winner as yet…

Wave energy conversion techniques

Oscillating water column (OWC)

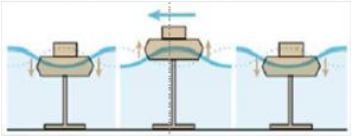


- The sea rises and falls within a chamber, compressing air which drives a turbine and generator to produce energy

Wavegen

Oscillating bodies

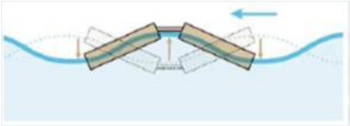
Buoyant body with fixed reference



- Energy is generated by the relative movement of a buoyant body with respect to another fixed body (anchored or submerged)

Powerbuoy

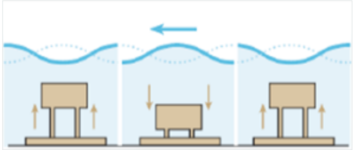
Buoyant body with mobile reference



- Energy is generated by the movement of a buoyant body on the surface, generally the relative movement between two connected sections

Pelamis

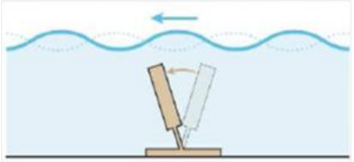
Archimedes effect



- An oscillating body moved by the pressure of the water column on top of it

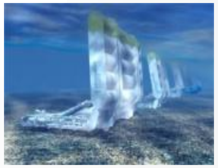
Archimedes Wave Swing

Impact



- A hinged flap pitches backwards and forwards as the waves hit its surface

Oyster



Overflow

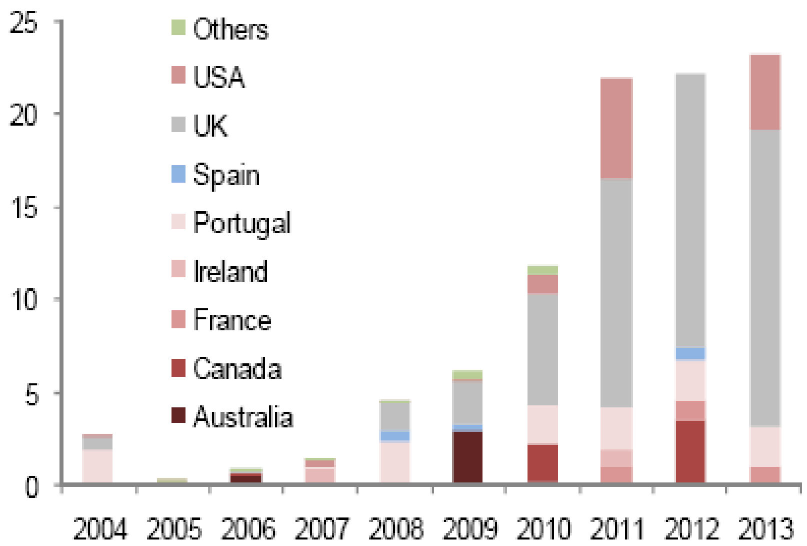
- A converter uses the potential power of the waves, stores the water that overtops a specific obstacle and drives it through a hydraulic turbine

Wave Dragon

Source: EVE, IEA-OES, EuroPraxis

... and given its emerging nature there are very different estimations for its market projections

Facilities envisaged per country in wave energy and marine currents (2009-2013, MW)



It is expected that 2013 will see accumulated power of 95MW (not including tidal facilities that are the only relevantly sized current commercial ventures)

Source: Douglas – Westwood (2010)

Different market projections

- Various organisations such as the British Carbon Trust and BWEA association or the international IEA - OES alliance estimate that the accumulated marine energy capacity will stand at around 2-5 GW in Europe in 2020
- A recent study by Pike Research (2009) comes up with more favourable estimations, putting the worldwide capacity around 3GW in 2015 with potential for 200GW by 2025 if solutions can be found for current technological barriers.
- Another report by Global Data (2010) quotes total capacity as 46GW in 2020, with the United States as the main power with 33GW followed by the United Kingdom with 2GW

Source: The Carbon Trust, BWEA, IEA-OES, Pike Research, Global Data

In any case, most sources agree that the sector will take off in the second half of this decade

energiBasque, the technology and business development strategy for energy in the Basque Country, identifies offshore among its segments…

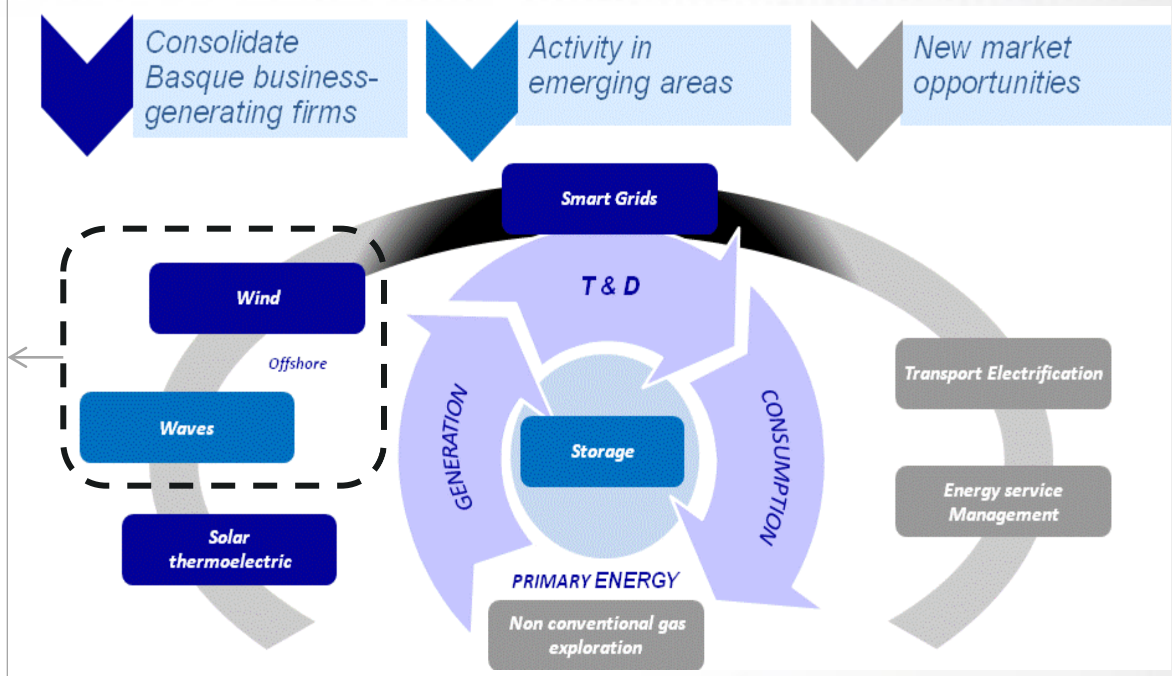
Wind energy strategy

The wind energy strategy seeks to support leading companies in developing a competitive range of products and services adapted to the increased power of wind turbines and to development of the offshore segment, thereby causing a catalytic effect on the entire value chain

Wave energy strategy

The wave energy strategy seeks to consolidate technology-based scientific solutions and a value chain with equipment, components and services specific to marine energy benefiting from the catalytic effect of the singular experiment infrastructure existing in the Basque Country

energiBasque priority energy segments



The wind energy strategy in energiBasque includes technological areas and lines that directly or indirectly affect offshore wind energy

Strategic Objectives	Technological areas	Technological lines
Supporting development of a cutting edge technological offer in segments of the chain of value where Basque companies have good prior positioning, in terms of components and equipment for wind turbines such as systems and services associated with wind farms in general.	Developing reliable, efficient equipment for high power wind turbines (>5MW)	• Developing mechanical and hydraulic equipment (actuators, gearbox, yaw systems, pitch systems, braking systems) • Developing electrical equipment (generator, medium voltage apparatus, control electronics, etc.) • Developing manufacturing processes for structural parts • Developing blade manufacturing technologies • Researching new materials
	Adapting and developing components, equipment and systems for offshore wind energy	• Developing new technologies for foundations, anchoring and floating structures • Studying new materials, treatments and corrosion-resistant coatings. • Developing offshore electrical evacuation equipment and systems • Improving the systems for monitoring, predictive maintenance and control of offshore wind farms • Optimising offshore services for installation, operation and maintenance
Encouraging adaptation of current product and service portfolio to larger wind turbines plus developing the offshore segment	Developing equipment to integrate wind energy into the electricity network	• Developing power electronics equipment for energy quality, protection, control and measuring (convertors, STATCOM, FACTS, etc.) • Technologies for integrating wind energy on a large scale
	Developing technologies to optimise the best use of the wind resource	• Researching resource evaluation techniques, both onshore and offshore • Spatial planning for wind farms

Source: energiBasque

The wave energy strategy in energiBasque aims to develop a specific chain of value making the Basque Country a benchmark region

Strategic Objectives

Supporting Basque companies in developing a specific offer for wave energy, both in convertor components (PTO systems) and in auxiliary equipment and services specifically for marine energy systems (such as energy transmission, power electronics, operation and maintenance)

Setting up initiatives that encourage positioning of the RTD+i agents network and the Basque chain of value as an international benchmark, starting by maximising the benefit generated by an emblematic infrastructure on a worldwide scale such as BIMEP

Technological areas

Technological lines

Developing equipment and components for wave convertors (operation and energy quality systems)

- Developing equipment and components for hydraulic PTO systems
- Developing equipment and components for mechanical PTO systems
- Developing equipment and components for linear generator PTO systems
- Designing energy quality equipment based on power electronics (convertors, storage systems)

Developing other equipment and auxiliary systems related to the infrastructure (anchoring, signalling, energy transmission and network connection)

- Designing and manufacturing anchoring systems
- Designing equipment for signalling and environmental monitoring
- Developing equipment and components for the energy transmission system (umbilical, static and dynamic cables, interconnections, connection boxes)
- Developing equipment and components to integrate the electrical energy into the grid (offshore and onshore substation equipment)

Promoting the auxiliary service offer in the infrastructure's life cycle

- Strengthening the Basque RTD offer in terms of companies owning convertors (research into new concepts, floating structure geometry analysis, certification for sensors in real operating conditions, etc.)
- Developing technologies to evaluate the marine resource and assess the quality of the location
- Developing technologies to assess the environmental impact
- Designing remote management, communication and monitoring systems
- Studying and optimising the operation, maintenance and workplace safety system in marine infrastructures
- Designing environmental surveillance systems

Source: energiBasque

The Basque Country has a very large group of companies either currently involved in or with the capacity and interest to offer products and services for offshore wind energy...

Basque companies currently involved in or with potential in offshore wind energy

1. AEROBLADE
2. ALBICEIN
3. AMPO
4. ARTECHE
5. ASSYSTEM IBERIA
6. ASTILLEROS BALENCIAGA
7. ASTILLERO IGNACIO OLAZIREGI
8. ASTILLEROS MURUETA
9. ASTILLEROS ZAMAKONA
10. AUTORIDAD PORTUARIA DE BILBAO
11. AUTORIDAD PORTUARIA DE PASAJES
12. BALANCE APPLIED ENGINEERING
13. BAM
14. BERGÉ Medium AMBIENTE
15. BOSCH REXROTH
16. CEGASA
17. CENTORK
18. CINTRANAVAL-DEFCAR
19. COBRA
20. CONSONNNI
21. ECN CABLE GROUP
22. EGT
23. ELECNOR
24. EUSKAL FORGING
25. GAMESA
26. GE POWER MANAGEMENT
27. GES
28. GLUAL HIDRÁULICA
29. GUASCOR WIND
30. HINE RENOVABLES
31. IBERDROLA ING. Y CONST.
32. IBERDROLA RENOVABLES
33. IDOM
34. IK4 RESEARCH ALLIANCE
35. INCOESA
36. INDAR ELECTRIC
37. INDRA
38. INDUPIME
39. INGE-INNOVA
40. INGENOR
41. INGETEAM ENERGY
42. INGETEAM MARINE
43. INTERTEK
44. ITXASKORDA
45. JEMA
46. KRAFFT
47. LA AUXILIAR NAVAL
48. LA NAVAL
49. LASA NAVAL
50. LAUNIK
51. LAZPIUR
52. LEABAI
53. LEKOIZPE
54. LEKUNBIDE
55. LKS INGENIERIA
56. MAESSA
57. MANDIOLA COMPOSITES
58. MANDRINADOS DE PRECISIÓN
59. MATZ-ERREKA
60. MECANIZADOS HARRI
61. MENSA
62. MESA
63. MIESA
64. MULTINACIONAL TRADE
65. NAVACEL
66. NAVIERA MURUETA
67. NEM SOLUTIONS
68. NEURTEK
69. OASA TRANSFORMADORES
70. OBEKI GROUP
71. OCINORTE
72. ORMAZABAL
73. PINE EQUIPOS ELÉCTRICOS
74. PINE INSTALACIONES Y MONTAJES
75. QUIMYCAT
76. REMOLCADORES IBAIZABAL
77. REMOLCADORES DE PASAJES
78. ROXTEC SISTEMAS PASAMUROS
79. RULITRANS INGENIEROS
80. SELECMAR
81. SENER
82. SIEMENS
83. SINTEMAR
84. SKF ESPAÑOLA
85. SLING SUPPLY INTERNATIONAL
86. SYSTEMS
87. TALLERES GOMETEGUI
88. TALLERES KAI ALDE
89. TAMOIN
90. TECNALIA
91. TECNOARANDA
92. TRADEX
93. TRATAMIENTO TÉRMICO TEY
94. URKUNDE
95. VICINAY CADENAS
96. ZINETI
97. ZIV
98. ZUMAIA OFFSHORE

Source: Basque offshore wind energy catalogue (Energy Cluster)

... These companies come both from the field of onshore wind energy and from the naval and marine services specialities field

... they also provide the necessary threads to weave industrial fabric in marine energies...

Basque companies with wave energy capacity

1. AEG POWER SOLUTIONS
2. ALKARGO, S. COOP.
3. ALSTOM HYDRO
4. ● AMPO-POYAM VALVES
5. ASMATU INGENIERÍA
6. ● ASTILLERO IGNACIO OLAZIREGI
7. ● ASTILLERO LA NAVAL
8. Low EL AGUA FACTORY
9. ● BAM
10. BATZ
11. ● BERGÉ
12. BOMBAS ITUR
13. ● BOSCH REXROTH
14. BOSLAN
15. ● CINTRANAVAL - DEFCAR, S.L.
16. ● COBRA (GRUPO COBRA)
17. DANOBAT
18. ● ECN CABLE GROUP, S.L.
19. ● ELECNOR
20. FAGOR AUTOMATION
21. GAIKER (IK4)
22. ● GES
23. ● GLUAL HIDRÁULICA
24. ● HINE, S.A.
25. ● IBERINCO
26. ● IBERDROLA RENOVABLES
27. ● IDOM
28. ● INDAR (INGETEAM)
29. INDASA
30. INDENOR
31. ● INGEINNOVA
32. ● INGETEAM
33. ● ITSASKORDA, S.L.
34. ● JEMA - JESÚS MARÍA AGUIRRE, S.A.
35. ● LASA NAVAL OTN
36. ● LAZPIUR
37. LEROY SOMER
38. LICAF, S.L.
39. MASER
40. MAVI FORMACION, S.L
41. METALÚRGICA MARINA, S.A.
42. ● MIESA
43. MONCOBRA (GRUPO COBRA)
44. MTS VALVES
45. ● MULTINACIONAL TRADE
46. ● NAVACEL
47. ● NEM SOLUTIONS
48. ● NEURTEK, S.A.
49. ● OASA TRANSFORMADORES
50. ● OBEKI
51. OCEANTEC
52. ● OCINORTE
53. ● ORMAZABAL
54. ● PINE (INGETEAM)
55. ● QUIMYCAT
56. RALPE
57. ● REMOLCADORES DE PASAJES (BERGÉ)
58. ● REMOLCADORES IBAIZABAL
59. ● RULITRANS INGENIEROS S.L.
60. ● SENER
61. ● SINTEMAR
62. STAS IBERICA, S.A.
63. ● TALLERES GOMETEGUI, S.L.
64. ● TAMOIN
65. ● TECNALIA
66. IK4-TEKNIKER
67. ● TRADEX
68. ● VICINAY CADENAS, S.A.
69. VOITH HYDRO
70. ZIGOR
71. ● ZINETI, S.A.
72. ● ZUMAIA OFFSHORE

● Companies that also have offshore wind energy capacity

Source: Basque offshore wind energy catalogue (Energy Cluster)

... with companies that strongly overlap (64%) with those dedicated to offshore wind energy, thus highlighting the similarities between both fields

nanoBasque

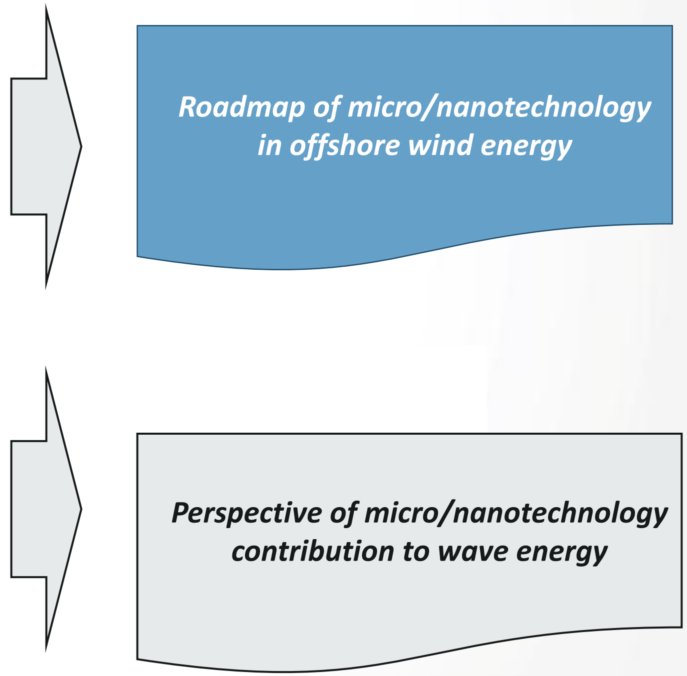
1. Introduction
2. **Methodology**
3. Micro/nano roadmap in offshore wind farms
4. Micro/nano perspective in wave energy

The roadmap focuses on offshore wind energy and extrapolates the results to obtain an initial overview of wave energy

- Given that technology and the market are far more developed for offshore wind energy than they are for wave energy, and in view of the areas shared by both, a different approach is taken to identify the contribution of micro/nanotechnology to each one

- **The first case analysed is offshore wind energy**, designing a complete and structured roadmap of micro/nanotechnology applications
  - The rest of the chapter presents the methodology followed in drawing up the roadmap

- **Wave energy** is still at the very early stages of development. This implies too little definition and too many uncertainties to make either effective or advisable an analysis such as that carried out for offshore wind energy
  - To obtain a first perspective of the contribution by micro/nano to the field of wave energy, an ad-hoc analysis is carried out based on the results obtained for offshore wind energy



The objective of the roadmap is to provide a visual idea of the potential of micro/nanotechnology in developing offshore wind energy…

Technical objectives

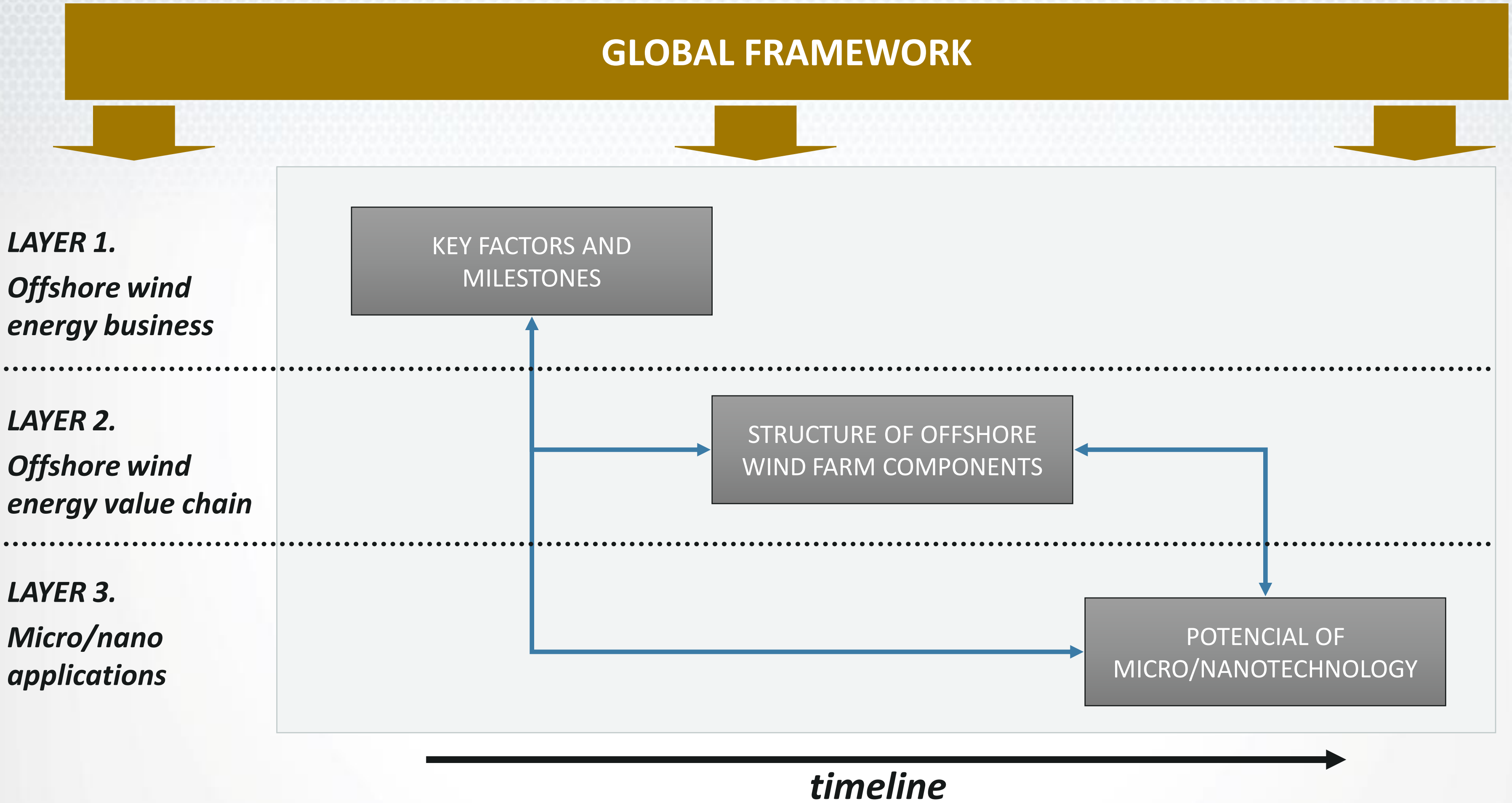
Global frame-work	Establish the potential of applying micro/nano to energy in a specific timeframe
Basque Country situation	Identify the current position of agents in the Basque Country as regards the global framework
Gaps	Identify the opportunities and challenges involved in developing micro/nano energy applications in the Basque Country

Management/process objectives

- Approach to supply and demand of micro/nano technologies in the Basque Country
- Pilot experience for extension of the exercise to other areas
- Define a Plan of Action for the nanoBasque Agency in the area of energy

… as a tool to unite Basque scientific/technological capabilities and business interests in the area

Drawing up a global framework follows a structured process based on identifying the keys to future competitiveness in the business…



… subsequently establishing its influence and demands on the different elements of an offshore wind farm and identifying the potential of micro/nano in providing solutions for these

Some basic concepts must be considered when designing this Global Framework

Offshore wind energy business

- **Guiding factors**: these are the main aims and challenges for the future to make an offshore wind energy business more competitive. So they represent the reasons for developing products and processes within the sector.
- **Milestones**: given that the guiding factors can be generally formulated and, in order to display their incidence over time, they are distinguished by a series of factors or achievements, known as milestones, that are more specific and so can be pinpointed in time.

Offshore wind energy chain of value

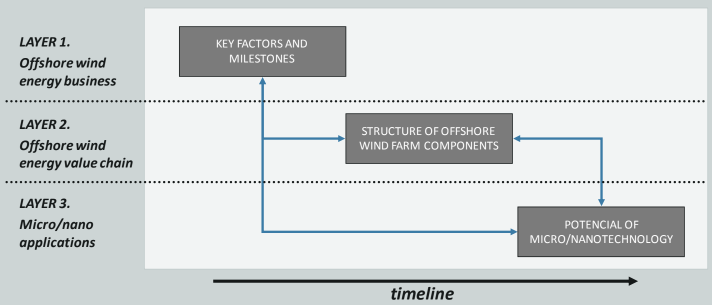
- An offshore wind farm's components are defined in a structure on which the guiding factors/milestones and nano/micro applications are fitted.
- This facilitates the specific perspective for companies in accordance with their position in the chain of value.

Micro/nano applications

- Firstly, the **micro and nano application areas** have to be identified in relation to the guiding factors/milestones and components for the previous layers' chain of value.
- Then, each area of application is looked at in greater depth, giving details of the different **micro/nano technology lines** that might crop up, their degree of maturity, etc.
- As much as possible, this involves differentiating the micro and nanotechnology applications.

Working from the Global Framework definition, dialogue is generated between micro/nano agents and the business demand...

Global Framework of micro/nano applications in offshore wind energy



Dialogue with agents from the micro/nano offer and the offshore wind energy business demand

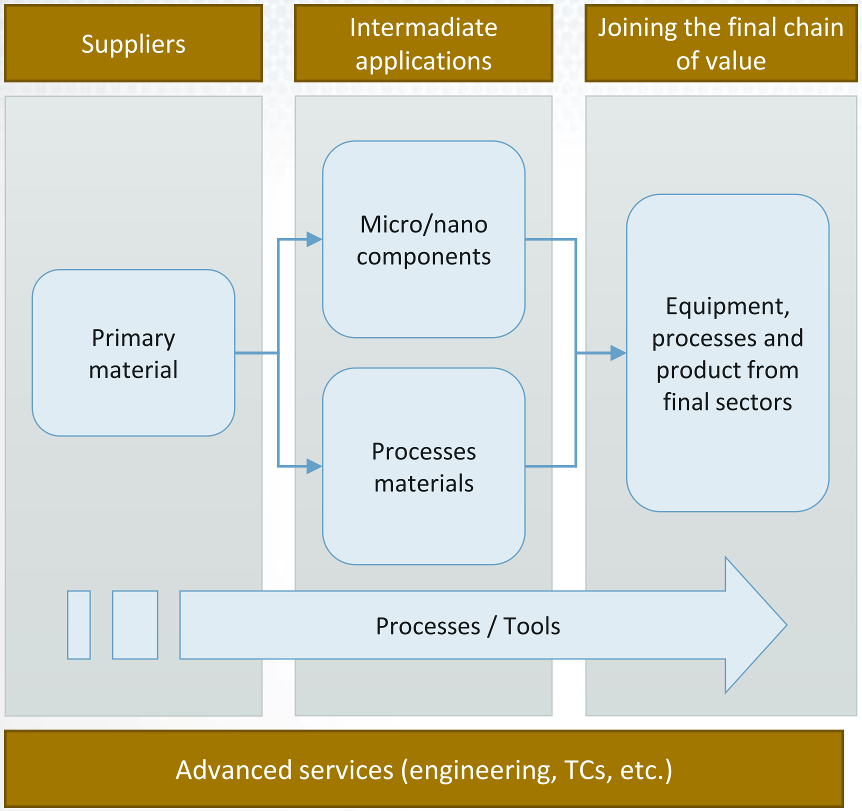
Global Framework contrast and improvement with contributions from Basque agents

Positioning of Basque agents (skills, current or planned activities)

Prioritising and identifying action lines/projects to be boosted

...focussing on contrasting and enriching the defined Global Framework and finding action priorities and lines for future collaboration between the two

As companies move into micro/nano technologies, different paths can be followed, forming a specific chain of value



Suppliers

- Micro/nano primary material suppliers (nanoparticles, polymers, microthreads, etc.)
- Manufacturers of machinery and tools intended for manufacturing micro and nano technology component products

Intermediate applications

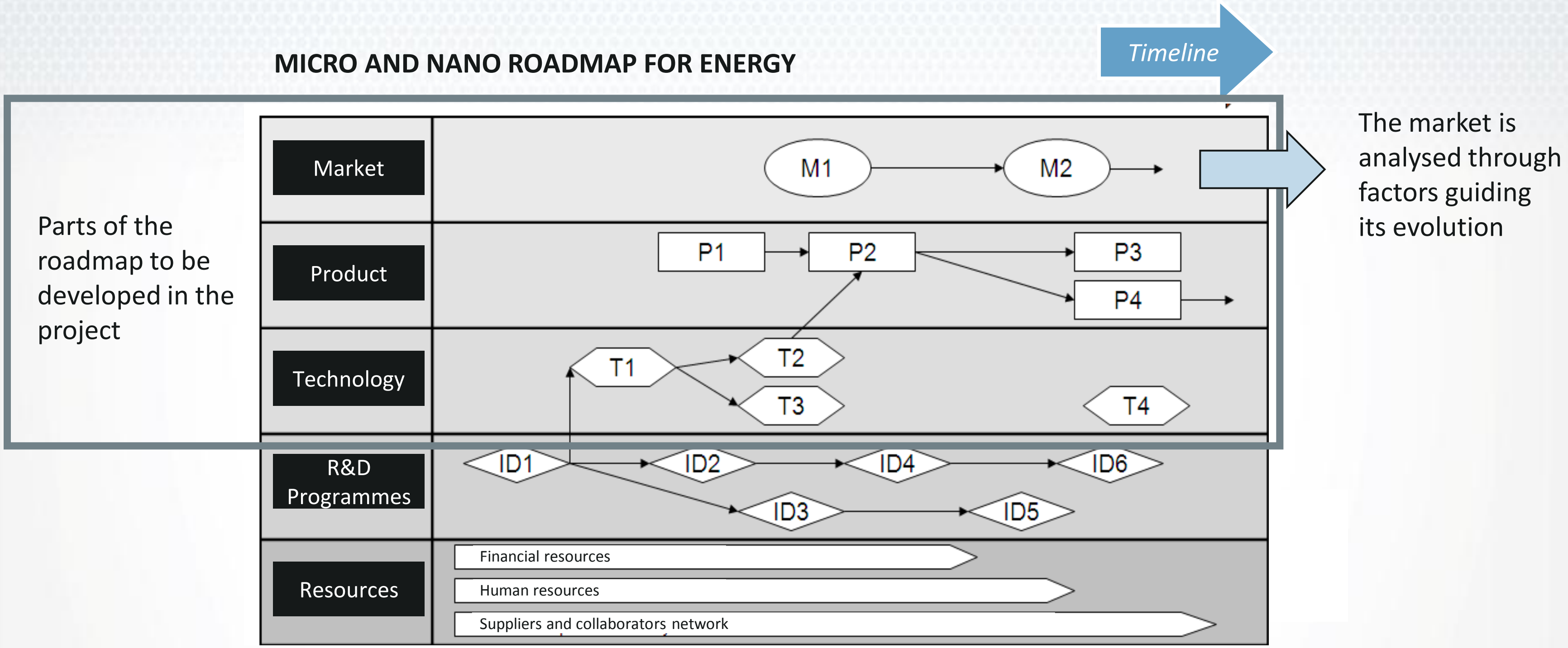
- Micro/nano component manufacturers (chips, microdevices, sensors, etc.)
- Companies that include micro/nano elements in conventional materials (nano-structured materials, adding nanoparticles, coatings, etc.)

Users

- Companies that incorporate micro/nano components into equipment intended to manufacture conventional products
- Companies that implement processes improved through using micro and nanotechnologies
- Companies that incorporate micro/nano components into their product

nanoBasque

Markets are understood by identifying and analysing factors that are going to determine how they change in the future



A series of guiding factors can be distinguished that boost and direct future development of offshore wind energy

Guiding factors for offshore wind energy

Reducing manufacturing costs	• Wind turbine production represents significant primary material consumption • The need to produce larger wind turbines requires serious work on reducing these costs.
Reliability and longer useful lifespan for components	• The vast investment made in manufacturing and installing wind turbines requires guarantees that it will work properly in the long term • Component reliability is necessary because repairs are expensive and require staff, material and support equipment to be mobilised at sea.
Remote monitoring and diagnosis	• The wind farm's distance and access difficulty, as it is in the sea, requires remote monitoring and diagnosis.
Economies of scale	• It is necessary to produce increasingly larger wind turbines generating a larger quantity of energy to be able to obtain economies of scale as soon as possible.
Optimising energy conversion and transmission	• Optimising energy conversion and transmission is vital to make the best possible use of the offshore wind farm's potential to supply energy to the grid.
Integration in the grid	• The increasing presence of renewable energy sources is a challenge for the grid. • The additional energy produced should be stored to be able to meet demand peaks or for cases of low energy production.
Security and integration with the environment	• Security is important to ensure the turbine's lifespan and that they operate correctly. • The environmental impacts are smaller in the case of offshore wind energy compared to onshore. Even so, there is still room for improvement to minimise how marine life might be affected.

Source: Europraxis analysis

These factors highlight a timeline of priorities and urgencies for technological development in relation to their impact on the business

Key factors	Milestones	Timeline		
		ST (-2013)	MT (-2015)	LT (-2020)
Reduced financing costs	Reduction in material costs: application of new materials to lower dependence on steel in the manufacture of towers and foundations			●
	Reduction in material costs: application of new materials to reduce the cost of blades		●	
	Reduction in nacelle and blade weight by using lighter structural and powertrain components	●		
Reliability and extension of the useful life of components	Extension of useful life in wind turbines to 25 years	●		
	Extension of useful life in wind turbines to 35 years			●
	Design of materials and coatings to prevent corrosion in marine structures		●	
	Development of coatings and new materials to prevent adverse conditions of abrasion and minimise rotor blade maintenance		●	
Remote monitoring and diagnostics	Remote monitoring and self-diagnostics by harnessing information on key parameters to control turbine condition	●		
Economies of scale	Increased blade and rotor size to increase energy harnessing ability			●
Optimisation of power conversion and transmission	Optimised energy generation: development of power electronics and generators operating at medium voltage		●	
	Optimised conversion of mechanical power (powertrain): development of new bearings systems to reduce loss through friction		●	
	Optimised conversion of mechanical power (powertrain): development of new lubricants to reduce loss through friction		●	
	Optimised conversion of mechanical power (powertrain): new transmission systems		●	
Integration to the power grid	Introduction of storage systems			●
Safety and integration with the environment	More effective protection against lightning strikes	●		
	Development of fire-protection systems	●		
	Minimization of interferences with air and sea radar systems	●		
	Reduction and analysis of operating noise and marine vibrations	●		

Source: Cluster de Energía / Europraxis analysis

nanoBasque

1. Introduction

2. Methodology

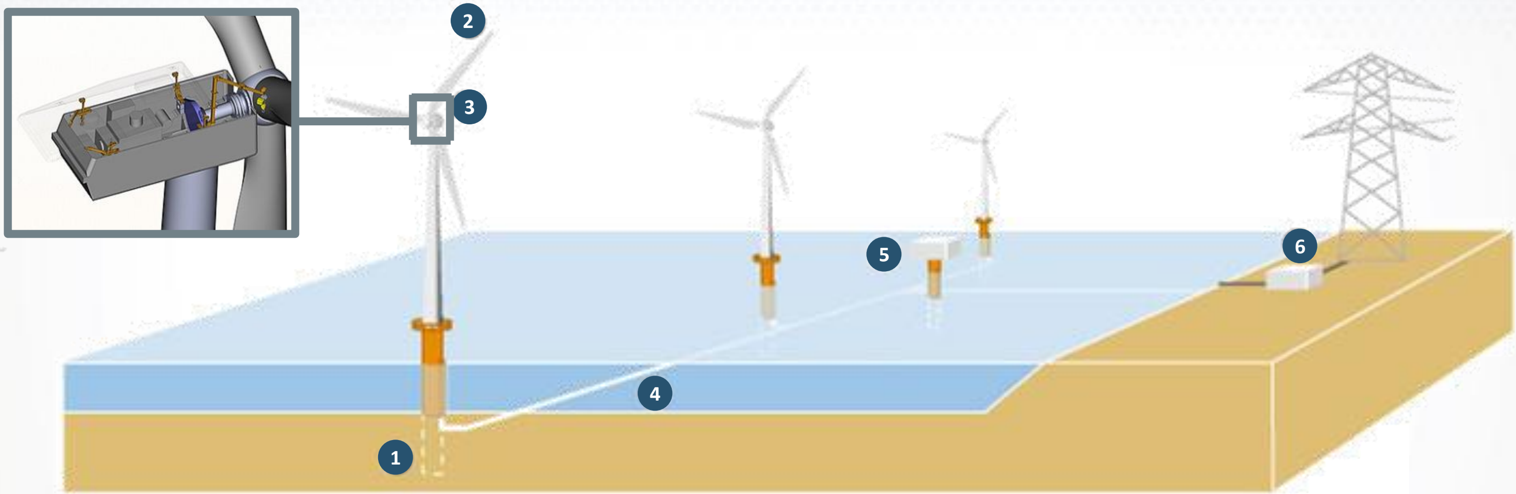
3. **Micro/nano roadmap in offshore wind energy**
    - Key factors of offshore wind energy
    - **Value chain of offshore wind energy**
    - Micro/nano applications in offshore wind energy
    - Positioning of Basque agents
    - Challenges and opportunities to be taken advantage of

4. Micro/nano perspective in wave energy

The elements of an offshore wind farm can be simplified…

Description

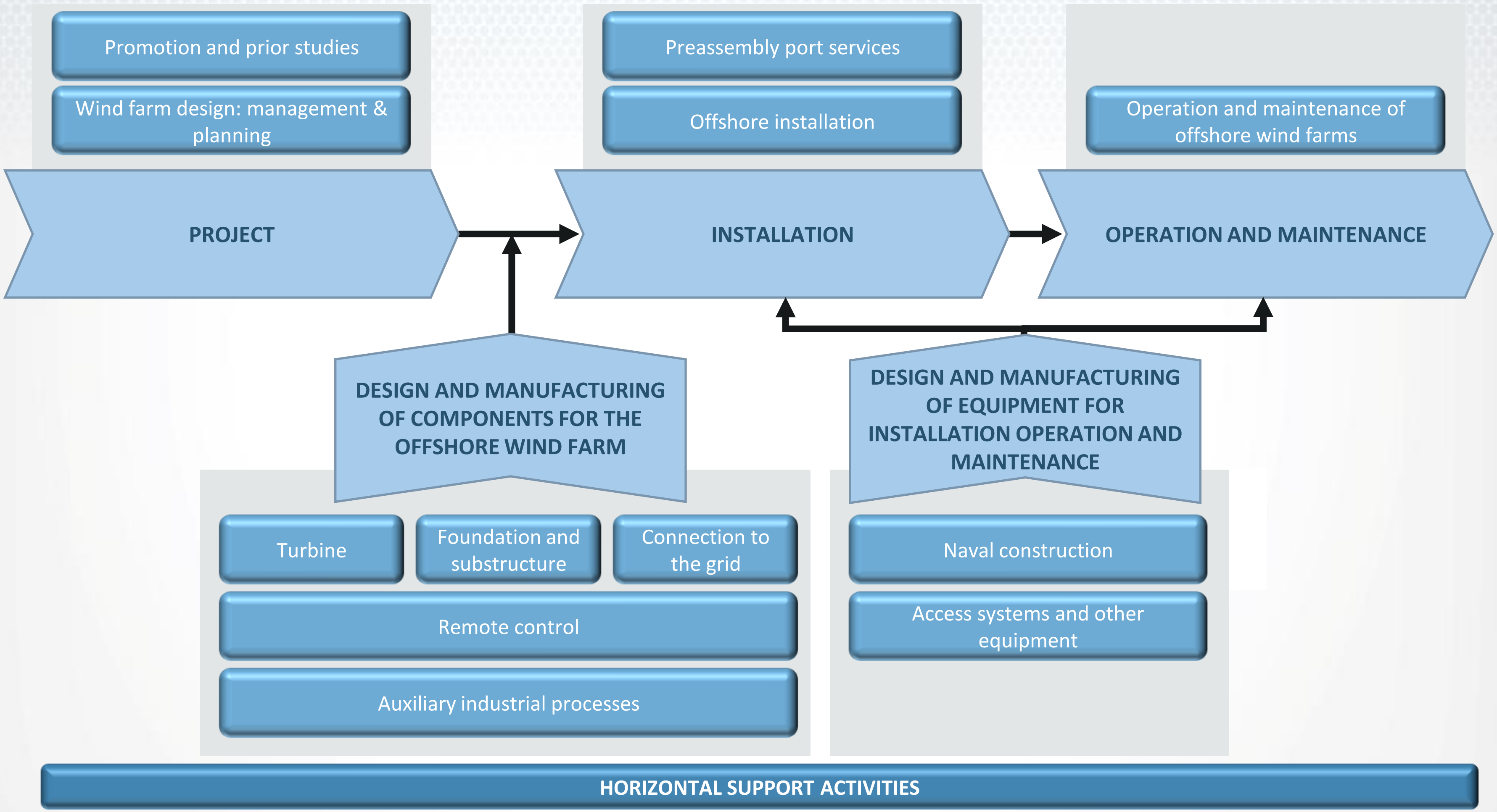
- Wind turbines are responsible for extracting energy from the wind by rotating the blades that transmit the axis rotation speed to a generator housed in the gondola or nacelle through gearings.
- The wind turbine is the industrial core of the wind sector and it is composed of over 8000 components
- An offshore wind energy industry is being developed requiring changes in the technologies used and in the supply chain



1. **Foundations and tower:** wind turbines should hold a defined position so they are not fixed to the seabed. The tower is fitted on this foundation with just the right height to expose it to the selected wind force
2. **Rotor:** the force of the wind turns the aerodynamically designed blades
3. **Gondola/Nacelle:** this is the part at the top of the tower to which the rotor is attached containing the parts to turn the mechanical energy into electrical energy. The gondola can be directed towards the wind blowing over the tower
4. **Underwater cable:** the electricity generated is transmitted to land through a network of cables fitted along the seabed.
5. **Offshore substation:** In order to minimise losses of electrical energy generated in the wind farm as it is transported to the coast, the voltage is raised in a substation located out at sea within the actual wind farm
6. **Installing the grid connection on land** depending on the existing grid, this might require a substation to be built

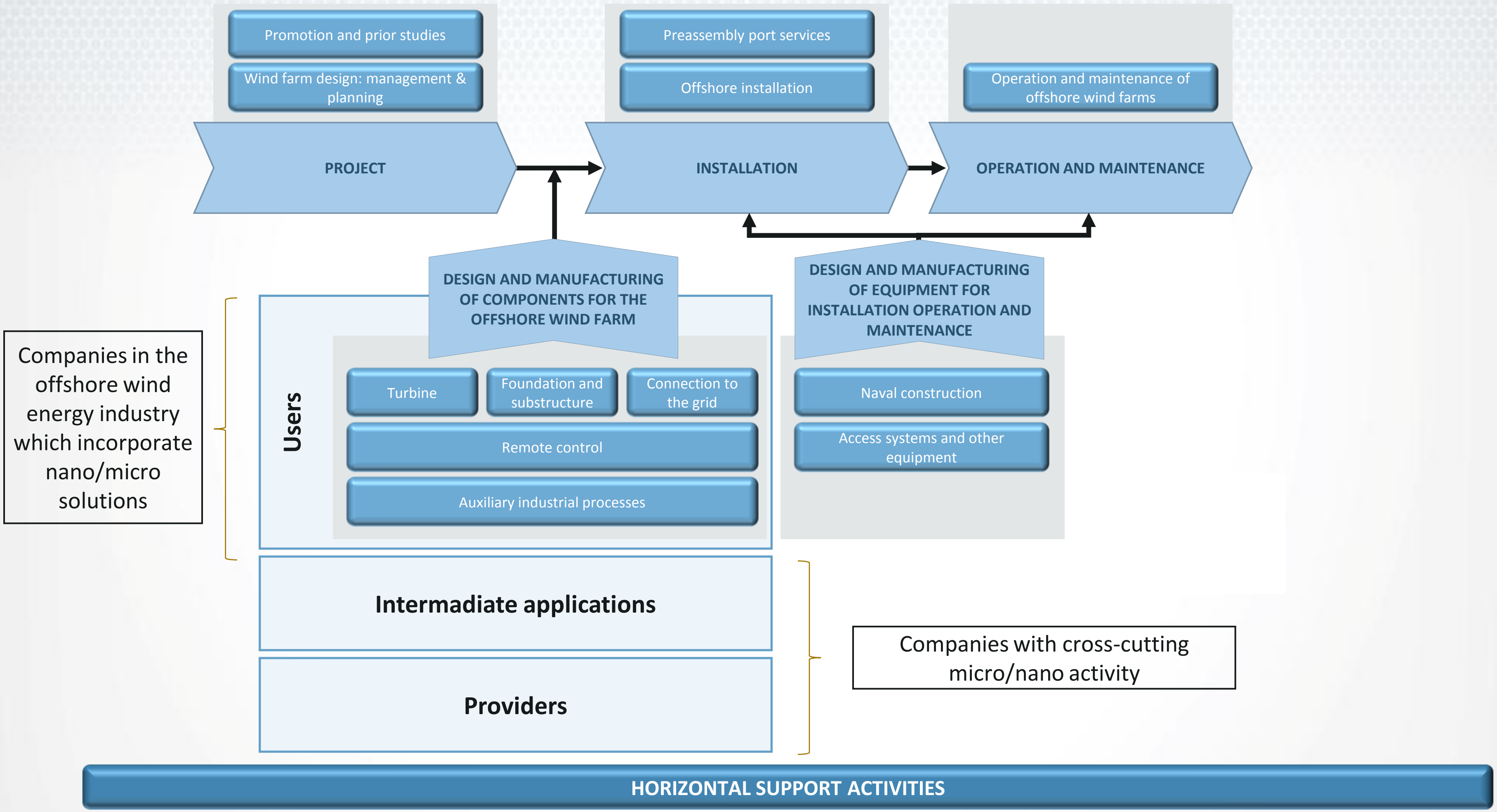
Source: Basque Country Offshore Wind energy Energy Catalogue

... but the business structure is more complex and covers all activities involved in the project phases, construction, operation and infrastructure maintenance...



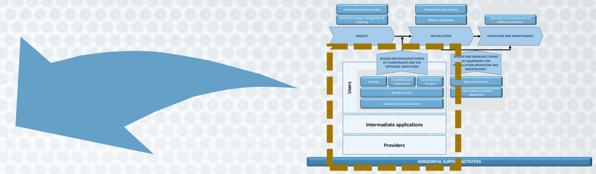
Source: Basque Country Offshore Wind Energy Catalogue

... and it can be even more complex if the integration with the value chain for the incorporation of micro/nanotechnologies is considered



Source: Basque Country Offshore Wind Energy Catalogue

However, this roadmap specifically concentrates on components for offshore farms…



Offshore wind energy value chain for the roadmap

Offshore farm components

Turbine

Rotor

Nacelle

Users

- Tower
- Blades
- Rotor hub
- Pitch and yaw systems
- Nacelle structure
- Multiplier & gearbox & powertrain
- Electrical system
- Brake and safety system
- Foundations and substructure
- Connection to power grid
- Remote control

Intermediate applications

Providers

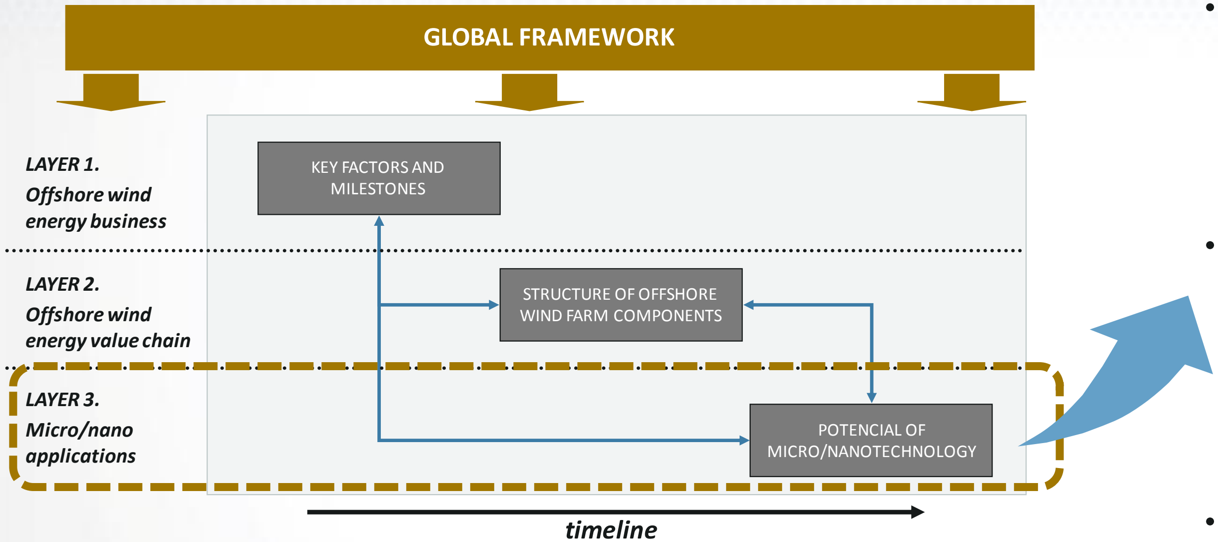
... where 11 components or fundamental systems really stand out

Turbine	**Tower**	• **Tower structure:** Part that supports the gondola and elevates the rotor at just the right distance. It can be between 40 and 100 metres high. They are usually made out of curved steel sections, 20-30 metres in diameter. • **Inner parts:** Lifting systems for staff access, components and spare parts and inner tower accessories such as handrails, metal platforms, ladders, etc. It also includes a lighting system. • **Joining and fastening parts:** Parts required to join sections together and attach the sections to the foundations. The sections are joined using heat-laminated steel flanges and bolts in the inner join and they are fastened to the foundations by temperate steel bolts.
Turbine – Rotor	**Blades**	The blades harness the wind and transmit the power to the hub. They are generally made out of a combination of epoxy resin and fibreglass. The latest developments for offshore blades reach 60 metres and weigh about 20 tonnes.
Turbine – Rotor	**Hub**	The function of this part is to hold the blades in position whilst they turn and so they undergo extreme tension. They are normally made of cast spheroidal graphite iron.
Turbine – Rotor	**Pitch and yaw systems**	• **Pitch system:** System that adjusts how much the blades open to make the most of the wind. It can be electromechanical made up of the electrical control opening system, a low torque engine and an encoder or positioner or electrohydraulics made up of a central supply unit, the hydraulic control and the hydraulic arm. • **Yaw system**: Electromechanical system that directs the rotational turn of the nacelle over the tower. It is made up of 6 fundamental parts: the position controller, the low torque turning engine, a gearing system for transmitting movement, a positioning encoder, a bearing and the system's casing.
Turbine – Nacelle	**Nacelle/gondola structure**	• **Gondola casing:** Outer part that holds and protects the wind turbine components. It is made of two structural parts: a cone that protects the rotor hub and several traps to get inside the gondola and a weather station. They are mainly made of polyester resin strengthened with fibre glass. • **Main body:** Structural part used to hold the weight of the gondola. It is generally made of steel by nodular casting or steroidal graphite.
Turbine – Nacelle	**Gearing and power train**	Set that converts the rotor's high torque, low speed mechanical energy into low torque, high speed mechanical energy suitable for the generation. It is mainly composed of an outer casing, gearing system, transmission axles and a coupling system.
Turbine – Nacelle	**Electrical system**	• **Generator:** This converts the mechanical energy into electrical energy. As opposed to a standard generator, it must be capable of working with the fluctuating mechanical energy supplied by the blades. It can be synchronous, asynchronous or permanent. • **Convertor:** This converts the direct energy into alternating energy for its network connection. • **Transformer**: This converts energy to high voltages suitable for the grid (from 690V to 20,000V).
Turbine – Nacelle	**Braking and security system**	This can adjust and stop the rotor turning. It comprises two independent systems: a hydraulic stopping system that is composed of a hydraulic pressure unit, a disk braking system and a hydraulic locking unit; and a mechanical locking system in the rotor for greater security.
	Foundations and substructure	Systems used to fasten the tower to the surface using direct fastening on the seabed or using floating foundations.
	Grid connection	• Connection using cables between the turbine and the grid. • HVAC (alternate current) cables are currently used although HVDC (direct current) systems will be necessary due to the distance of some projects from the coast to reduce losses during transmission and improving electricity generation with variable winds.
	Remote control	Control of operation and faults in the turbine and the wind farm.

nanoBasque

1. Introduction
2. Methodology
3. **Micro/nano roadmap in offshore wind energy**
   - Key factors of offshore wind energy
   - Value chain of offshore wind energy
   - **Micro/nano applications in offshore wind energy**
   - Positioning of Basque agents
   - Challenges and opportunities to be taken advantage of
4. Micro/nano perspective in wave energy

The third layer of the global framework consists of identifying the potential contribution from micro/nanotechnology...



Layer 3. Micro/nano applications

- Firstly this aims to identify the **areas for applying micro and nano technology,** in relation to the guiding factors/milestones and components of the chain of value from previous layers.
- Later, it goes into greater depth into each of these areas of application, detailing the different **micro/nano technological lines** that can come into play, how mature they are, etc.
- As much as possible, we aim to differentiate between micro and nano technology applications

... to the future demands and aims for offshore wind energy that are defined in the guiding factors and their milestones

A series of applications have been identified, for which an analysis was made of their area of application and of the related micro/nano developments

Micro/nano applications identified

1. Combination of new structural materials
2. New materials offering greater cost/behaviour balance
3. Solutions to prevent corrosion and fouling
4. UV degradation prevention
5. Improved tribological systems
6. Sensors for monitoring blade condition
7. Protection systems against impact of rays and fires
8. Anti-radar systems
9. Solutions for analysis and reduction in noise and vibration
10. Coating to improve resistance to erosion and wear (turbine structure)
11. Ice-phobic surfaces

Micro/nano focus

n	Nano applications
µ	Micro applications

Description of each application

Area of application	• Explanation of the application with the business layers: • Identification of associated key factors/milestones • Identification of value chain components affected • Description of the business problem and the solution/improvement obtainable through micro/nanotechnology
Lines of micro/nano development	• Identification of the different lines of micro and nanotechnology development on which the application could be based • Degree of maturity of the technology/application ● Current application ◐ Pre-commercial application ○ Potential application

Remember that the identified applications differ by scope...

Identified applications	Scope*	Contribution micro/nano**
1. Combination of new structural materials	◑	◔
2. New materials offering greater cost/behaviour balance	●	◕
3. Solutions to prevent corrosion and fouling	●	◕
4. UV degradation prevention	◔	◕
5. Improved tribological systems	●	◕
6. Sensors for monitoring blade condition	◑	◔
7. Protection systems against impact of rays and fires	◔	◑
8. Anti-radar systems	◔	◑
9. Solutions for analysis and reduction in noise and vibrations	◑	◔
10. Coating to improve resistance to erosion and wear (turbine structure)	●	◕
11. Ice-phobic surfaces	◑	◕

(*) Scope of the identified application in terms of scope and volume of research and technological development work that it might represent
(**) Contribution of micro/nanotechnologies to developing the identified application

... and the contribution from micro/nanotechnologies to develop them

These micro/nanotechnology applications contribute to guiding factors through different chain of value components

Guiding factors	Milestones	Tower	Blades	Hub	Pitch and yaw systems	Gondola structure	Gearing	Electrical system	Braking and security system	Foundations and substructure	Grid connection	Remote control
Reducing manufacturing costs	New materials replacing steel	1								1		
	New materials to reduce blade costs		2									
	Reducing weight		2			2						
Reliability and longer useful lifespan for components	Extending wind turbines' useful lifespan	3, 10	3, 4, 7, 9, 10, 11	3, 9	5, 9	4, 7, 10	5, 9	3		3, 10	3	
	Avoiding corrosion and fouling	3	3	3				3		3	3	
	Avoiding adverse abrasion conditions and minimising maintenance		10		5	10	5					
Remote monitoring and diagnosis	Picking up turbine condition information		6						6			6
Economies of scale	Increase in size of blades and rotor		2									
Optimising energy conversion and transmission	Power electronics and generators that operate at medium voltage											
	Bearing to reduce losses through friction				5		5					
	Lubricants to reduce losses through friction						5					
	New transmission systems											
Integration in the grid	Implanting storage systems *(See roadmap for the micro/nano technology application in Energy Storage)*											
Security and integration with the environment	Lightning protection systems		7									
	Fire protection systems		7			7						
	Minimising interference		8									
	Reducing and analysing operational noise and vibrations		9			9	9					

No. Application of micro/nanotechnologies that contributes to the guiding factor milestone

nanoBasque

1 Combination of new structural materials

Areas of application

Key factors	Milestones	Value chain
Reduced production costs	New materials to substitute steel	Tower, foundations and substructure

- Tower height is essential in increasing the capacity to generate electric power; the higher it is from the ground, the higher the speed of the wind it can harness.
  - For example, a 25-metre turbine would be exposed to winds of 5.5 m/sec., while a turbine measuring 100 m would harness winds of 6.7 m/sec. This means a speed increase of 40%.
- Towers require very large amounts of steel. Increased height will mean greater steel consumption due to the extra height and diameter of the sections in these higher towers.
  - The tower of a 2.5 MW offshore turbine amounts to 11% of its cost.
- New materials and solutions are therefore required to reduce steel consumption.

Sources:
141st annual meeting of The Minerals, Metals & Materials Society;
DeepCwind Consortium;
Composites World

Focus

n

Degree of maturity of the application

Pre-commercial application

- *The University City of Hong Kong has designed towers with thinner walls*
- *First offshore prototypes installed by a consortium of companies and universities (DeepCwind) in Maine (USA) with offshore towers for great depths that use a combination of composites and nanocomposites*

Micro/nano developments

- Reduced consumption of resources by thinning turbine tower walls thanks to the optimised combination of materials with different properties:
  - Coating of metal nanocrystals to increase resistance of the original metal material.
    - This is achieved by means of Surface Mechanical Attrition Treatment (SMAT)
- Reduced consumption of resources by using new materials to replace the steel:
  - Huge structures of metal matrix composites reinforced with nanoparticles.

Coatings with metal nanocrystals and metal matrix composites reinforced with nanoparticles are the technologies that offer the greatest potential for this application

2

New materials offering greater cost/behaviour balance

Areas of application

Key factors	Milestones	Value chain
Reduced production costs	New materials for lower blade cost	Blades
Reduced production costs	Reduced weight	Blades and nacelle structure
Economies of scale	Increased blade and rotor size	Blades

- Increased blade size is essential in harnessing a greater amount of kinetic energy from the wind.
  - Blades with diameters of 250 metres are being considered for turbines capable to produce 20MW by 2020. However, with current characteristics, blades of this size would weigh 150 tons.
- To make longer blades possible, greater rigidity and materials to facilitate their processing are required.
- Less weight and material consumption are important for increased turbine performance:
  - Today the nacelle structure and blades are made in polymer matrix composites (polyester or epoxy) reinforced with low-cost glass fiber (E-glass fiber)

Sources:
Dawei Hu, University of London. *Development of the epoxy composite complex permittivity and its application in wind turbine blades;* Society of Plastics Engineers; Composites World; Science Daily; Daniel R. Bortz, César Merino, Ignacio Martín-Gullón. *Augmented fatigue performance and constant life diagrams of hierarchical carbon fiber/nanofiber epoxy composites*

Focus

n

µ

Degree of maturity of the application

Pre-commercial application

- *Bayer has developed polyurethane composites reinforced with carbon nanotubes to produce blades*
- *Gamesa has created a laboratory in Singapore dedicated to research into nano-reinforcements for incorporation to the blade composite*

Micro/nano developments

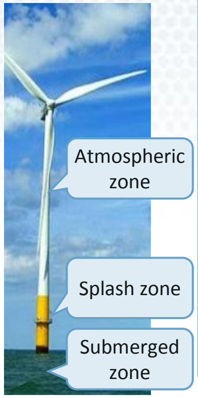
- Micro/nanoreinforced composites may be used to achieve greater blade size and to reduce the consumption of raw materials:
  - The incorporation of carbon nanotubes/nanofibers to fiberglass reinforcement of the polymer matrix means that less material is required and greater size can be achieved due to improved resistance of the composite. Some examples of these carbon nano-reinforcements are:
    - CNF (Carbon Nanofibers)
    - CNT (Carbon Nanotubes): Single-Walled Nanotubes (SWNT) and Multiwall Carbon Nanotubes (MWNT)
  - Organic matrix composites reinforced with nanofibers obtained from the organic waste process in order to substitute fiberglass and carbon reinforcements.

The impact of new materials used in the blade production process must be considered. Blades on which carbon nano-materials such as CNF are used are between 1.4 and 7.7 times more energy intensive than conventional blades (Merugula, Khanna and Bakshi, 2010)

3 Solutions to prevent corrosion and fouling

Areas of application

Key factors	Milestones	Value chain
Reliability and extended useful life of components	Prevent corrosion	Tower, Blades, Hub, Foundations & Substructure, Electrical system and Grid connection
Reliability and extended useful life of components	Extended useful life	Tower, Blades, Hub, Foundations & Substructure, Electrical system and Grid connection



- The marine environment increases the damage caused by corrosion because of its humidity, salt and the presence of dust and particles:
  - The structure of an onshore turbine loses around 200-400 g/m² of mass and 25-50 µm of volume a year, while in an offshore turbine these losses are approximately and respectively 650 -1500 g/m² and 80-200 µm.
- Moreover, the fouling, and specially the biofouling (the accumulation of microorganisms, plants, algae or animals on wetted surfaces) of the submerged zone can make the problems related to corrosion worse.
- Solutions for protecting the turbine against corrosion and fouling depend on the area to be protected.

Sources:
University of Southampton. *Wind Energy - Challenges for Materials, Mechanics and Surface Science*; Sintef. *Advanced Multifunctional Coatings to Offshore Wind Turbines*; Zaki Ahmad, Faheemuddin Patel . *Development of Novel Corrosion Techniques for a Green Environment*; Fraunhofer. *Chemical functionalization of nanoparticles*

Micro/nano developments

- Coatings containing nanomaterials, micro/nanoparticles and microcapsules that improve protection against corrosion and fouling :
  - Self healing based on microcapsules with healing agents
  - Graphene coatings:
    - Graphene layers generate an energy shield against oxygen atoms to prevent corrosion
  - Coatings with ceramic nanoparticles, CNT (carbon nanotubes), ZnO, TiO_2, ZrO_2, Al_2O_3 or CeO_2.
- Composites with nanomaterials that improve blade protection against corrosion:
  - Although polymer matrix components offer good resistance to corrosion, extended exposure to such corrosion damages their properties

Focus

n

µ

Degree of maturity of the application

● Current application

- *Paint Protection System commercialises paints with nanoparticles that protect the turbine against corrosion*
- *Nanyang Technological University (NTU), together with Rolls Royce, Vestas, Keppel Offshore & Marine and DNV, research components with nanomaterials for improved behaviour in preventing corrosion*

The marine environment is key in determining this important necessity

4

UV degradation protection

Areas of application

Key factors	Milestones	Value chain
Reliability and extended useful life of components	Extended useful life	Blades, nacelle structure

- Today blades and the nacelle structure are made using polymer matrix composites reinforced with glass fibres.
- Work is underway with different composites in the endeavour to produce different solutions for obtaining larger size, lower weight and greater resistance.
- Although the composites have obvious advantages, long exposure by this kind of material to UV rays has an adverse effect on its properties:
  - The polymers used to make composites absorb UV rays. This triggers photolytic reactions, thermal oxidation and photo oxidation that break the carbon-hydrogen chains, cause degradation of the polymers and external stress

Sources:
Ramazan Asmatulu. *Using graphene in coating materials to prevent UV degradation on advanced composite materials*; Wichita State University. *UV Degradation Prevention on Fiber-Reinforced Composite Blades*

Focus

n

µ

Degree of maturity of the application

● Current application

- *Coating solutions containing nanomaterials already exist for blades and nacelle structures (i.e. Bayer and Pain Protection System)*

Micro/nano developments

- Paints with micro/nanoaditives that protect the blades and the nacelle structure against UV aggression without adding weight:
  - For example, coating paints reinforced with graphene
- Polymer matrix composites reinforced with glass fiber and inorganic nanoparticles.
  - Inorganic nanoparticles that have shown their effectiveness in this respect are: carbon nanotubes (CNT), ZnO, $CdSe$, TiO_2, ZrO_2, Al_2O_3 and CeO_2.
  - In addition to these, composites can have a polyethylene, polyurethane, fluorinated polyurethane, polyester, polyamide or organosilane matrix.
  - This type of composites had advantages over coating paints including greater durability.

UV rays damage the parts of the turbine made with polymer matrix composites

5 Improved tribological systems

Areas of application

Key factors	Milestones	Value chain
Reliability and extended useful life of components	Extended useful life	Pitch & yaw system and multiplier
	Prevent abrasion and minimise maintenance	Pitch & yaw system and multiplier
Optimised energy conversion and transmission	Bearings to reduce loss caused by friction	Pitch & yaw system and multiplier
	Lubricants to reduce loss caused by friction	Multiplier

- The turbine transmission system is designed to have a useful life of 20 years. However, their actual useful life is no more than 5 years (University of Southampton).
  - The complete transmission system costs between £100,000 and £300,000.
  - Added to this price is the cost of installation far out at sea and the potential delays which may occur due to adverse weather conditions.
- 60-85% of transmission system failures are caused by problems with the bearings
- Marine corrosion also shortens the useful life of bearings; they must therefore be protected against this threat
- Additionally, correctly functioning bearings guarantee optimum transmission of the energy harnessed by the rotor.

Sources:
University of Southampton. *Tribology and corrosion aspects of wind turbines*; US Department of Energy. *Wind Turbine Tribology Seminar*; SINTEF. *Advanced Multifunctional Coatings Applied to Offshore Wind Turbines*

Focus

n

μ

Degree of maturity of the application

● Current application

- *Argonne National Laboratory is working to create new lubricants with nanoparticles*
- *REWITEC has treated 600-700 Gamesa, Vestas, GE and Nordex turbines with nanoparticles*

Micro/nano developments

- Lubricants with nanoparticles and nanofluids:
  - Lubricants with nanoparticles, nanoadditives and hybrid fluids (i.e. nanoboron or MoS_2)
  - Macromolecular nanolubricants
  - Nano-colloidal dispersion in oils
  - Green lubricants based on solid lubricants
- Nanocomposites for the production of more resistant bearings
- Nano/micrometrical or nanostructured selflubricating tribological coatings with high resistance to wear and low coefficient of friction:
  - Metallic, ceramic or polymeric coatings with highly scratch resistant nano/microparticles
  - Mechanically resistant nanocoatings
  - Coatings based on metal matrix composites with nano/microparticles for the reduction of the friction coefficient

60-85% of transmission system failures are caused by problems with the bearings

6

Sensors for monitoring blade condition

Areas of application

Key factors	Milestones	Value chain
Remote monitoring and diagnostics	Harness information on turbine condition	Blades, Safety & brake systems, Remote control

- The distance of turbines from dry land and difficult access due to their location translates into greater concern regarding to harnessing information on their condition by remote control.
    - Additionally, there is an increasing trend to install turbines even further from the coast due to the fact that wind power is greater. This is taking place parallel to the development of floating turbines.
- Remote monitoring and diagnosis are important for the early detection of damage and faults.

Sources:
Science Daily; Nanomagazine

Focus

n

µ

Degree of maturity of the application

○ Potential application

- *Bayer and the University of Houston are working to incorporate nanosensors to the blades*
- *A consortium lead by IMEC and compound with Fraunhofer and the University of Gent, among others, is carrying out a research work on the use of micro and nanotechnologies to control the blade condition (SMARTFIBER, 2010-2013 VIIPM)*

Micro/nano developments

- Installation of nanosensors on the blades:
    - Polymer-nanotube composites as a way to detect changes in environmental conditions using their electrical properties
- Paint formed with carbon nanotubes interfaced with wireless communication nodes with power harvesting and warning capability to remotely detect any unseen damage such as micro-cracks in a wind turbine concrete foundation
- Miniaturised structural monitoring system with autonomous readout microtechnology and fiber sensor network
    - Smart system which integrates optical fibber sensor technology, nanophotonic chip technology and low-power wireless technology.

Remote monitoring and diagnostics would mean savings on maintenance costs throughout the entire turbine life cycle due to the early detection of damage and evaluation of repair requirements

7 Protection systems against impact of rays and fires

Areas of application

Key factors	Milestones	Value chain
Safety and integration with the environment	Lightning protection systems	Blades
	Fire protection systems	Blades, nacelle structure
Reliability and extended useful life of the components	Extended useful life	Blades, nacelle structure

- Lightning strikes to offshore turbines is an important problem given that 10% of breakdowns occur for this reason:
  - A bolt of lightning can damage the blades or cause their surface to crack due to the arch produced.
  - Although the blades are fitted with lightening rods, the heat of the lightning bolt can damage or even melt the rods, leaving the blades unprotected against subsequent strikes.
- Lightning strikes are the main cause of fire on wind turbines:
  - The glass fiber used to make the blades and the nacelle structure and the petroleum oils used to lubricate the bearings helps the fire to ignite.
- To extend useful turbine life, protection systems must be created to withstand lightning strikes and prevent fire from spreading.

Sources:
Patentdocs

Focus

n

µ

Degree of maturity of the application

Pre-commercial application

- *Bayer is working on the use of carbon nanotubes to solve this problem*
- *Vestas has patented a system of lightning receptors coated with carbon nanotubes*

Micro/nano developments

- Coating the blades with carbon nanotubes to obtain high conductivity capable of preventing an electric arc on the blade and to improve resistance to fire:
  - Applying a CNT layer provides higher conductivity than a metal coating, but does not create any extra weight.
- Paint coatings with flame retardant micro/nanoadditives for blades and the nacelle
- Lighting rods coated with carbon nanotubes (CNT) or lighting rods based on metal matrix composite reinforced with carbon nanotubes to improve resistance to lightning strikes:
  - CNTs have a higher conductivity, thermal stability and melting point than most metals; they are also more resistant to corrosion
- Micro/nanostructured organic/inorganic hybrid surfaces

According to a study carried out by the US Department of Energy, 8 out of every 100 turbines are struck by lightning at some stage in their useful lives

8

Anti-radar systems

Areas of application

Key factors	Milestones	Value chain
Safety and integration with the environment	Minimisation of interferences	Blades

- Blade movement causes interferences in radar systems
- The presence of numerous turbines in a farm creates so much "noise" in the radars that it is difficult to detect the present of planes, even in the case of military radars
- This system is even more relevant in countries clearly committed to wind technology, where the question of national security is also especially important, such as the USA and the UK
- The use of stealth technologies that make military planes "invisible" holds enormous potential in its application.
    - Military research in this field is very longstanding
    - These are relatively simple technologies for incorporation to the field of wind power

Sources:
Sandia National Laboratories. *Radar-Cross-Section Reduction of Wind Turbines*

Focus

n

Degree of maturity of the application

Pre-commercial application

- *3M is carrying out research into the use of paints with carbon nanotubes for use on blades*
- *The University of Michigan is carrying out research into the possibility of incorporating carbon nanotubes to the blade composites*
- *Vestas has developed, with a company dedicated to military stealth, a blade prototype that solves this problem*

Micro/nano developments

- The use of carbon nanotubes (CNT) is a common subject among the main micro/nano research lines. The carbon nanotubes are the darkest materials known and surfaces covered with CNTs are capable of absorbing a wide spectrum of light, including radio waves, visible light and even ultraviolet rays.
    - Carbon nanotube paint coatings
        - The blades coated with these paints do not rebound radar signals
    - Use of nanocomposites for the manufacturing of blades
        - Blades of composites with interior layers of CNT-infused fiber to absorb and dissipate radar energy

Vestas and a company dedicated to defence solutions are working to solve this problem

9

Solutions for analysis and reduction in noise and vibrations

Areas of application

Key factors	Milestones	Value chain
Safety and integration with the environment	Reduction and analysis of operational noise and vibrations	Blades, multiplier, nacelle structure
Reliability and extended useful life of the components	Extended useful life	Blades, Hub, Pitch & yaw systems, multiplier

- Wind turbines generate operational noise that generally falls into two categories:
  - Mechanical vibrations due to movement of the bearings
  - Aeroacoustic noise due to movement of the blades and their interaction with the wind
- The problem of offshore turbines differs from the case onshore:
  - Although most offshore turbines are near the coast, they cause a relatively low nuisance in towns and cities
  - The noise causes vibrations transmitted throughout the structure and into the sea. This could have a negative effect on and cause behavioural changes in fish and sea mammals. Offshore turbines must therefore minimise the noise and vibrations they produce and transmit to the marine environment.
- Apart from noise and vibration reduction, it is necessary to monitor the vibration level in order to detect failures prematurely

Sources:
Science Daily; *Sandia National Laboratories*. Survey of Techniques for Reduction of Wind Turbine Blade Trailing Edge Noise; WindPower Engineering and Development. *Intelligent vibration monitoring for wind plants*

Focus

n

μ

Degree of maturity of the application

Pre-commercial application

- *Argonne National Laboratory and REWITEC are working on solutions for mechanical vibration*
- *Windblade Shield TM is working on coatings containing nanoparticules to reduce aeroacoustic noise emissions*

Micro/nano developments

- Nanotechnology offers solutions for reducing mechanical vibrations and aeroacoustic noise:
  - Mechanical vibrations:
    - Lubricants with nanoparticles for improved friction and reduction of the resulting noise
    - Isolation of the nacelle structure with material that absorbs the noise produced in its interior, i.e. using nanoscopic fibres formed by carbon nanotubes, boron nitride nanotubes, and titanium dioxide nanotubes
  - Aeroacoustic noise:
    - Coating blades by means of nanoparticules with water repelling characteristics to prevent the formation of ice helps to reduce noise
- In the case of vibration analysis, the use of MEMS accelerometers (microelectromechanical systems) allow to develop cheap CMB systems (Condition-Based Monitoring) in real time

Marine vibrations alter the life of fauna and may, among other effects, cause fish to change their behaviour

10 Coating to improve resistance to erosion and wear (turbine structure)

Areas of application

Key factors	Milestones	Value chain
Reliability and extended useful life of components	Extended useful life	Blades, nacelle structure, tower, substructure and foundations
	Avoid abrasion and minimise maintenance	Blades, nacelle structure

- Wind turbines suffer from erosion and wear due to the passing of time, their marine location and the aggression of elements like dust and sand, acid rain and abrasion caused by exposure to the sun. This all represents a threat to extension of their useful lives and place even greater accent on the problem of corrosion
- Increased useful life of offshore turbines is necessary if investment in this kind of power production is to become more attractive:
  - Consideration is being given to extend the useful life of turbines to 25 years by 2015 and to 30 years by 2020

Sources:
SINTEF. *Advanced Multifunctional Coatings Applied to Offshore Wind Turbines*

Focus

n

µ

Degree of maturity of the application

Pre-commercial application

- *Nowadays there are products that contain nanoparticles to protect turbines against the said aggressions (i.e. Bayer, REWITEC, Paint Protection System)*

Micro/nano developments

- Nano/microcoating technologies can help to improve resistance to erosion and wear:
  - Magnetic silica nanoparticles
  - Polystyrene nanoparticles
  - Biopolymers microparticles
  - Inorganic spherical nanosized particles
  - Hybrid organic/inorganic nanoparticles
  - Inorganic nanosized tubules
  - Inorganic nanorods
- Self-cleaning nanocoating technologies
  - i.e. paints with self-healing micro/nanoadditives

Work is underway on the need to increase the useful life of turbines to 25 years by 2015 and 30 years by 2020

11 Ice-phobic surfaces

Areas of application

Key factors	Milestones	Value chain
Reliability and extended useful life of components	Extended useful life	Blades

- Low winter temperatures in offshore locations (Northern Europe) can create ice on the blades.
  - The accumulation of ice generates additional weight on the blades that can reduce the energy production of the wind turbine and even completely paralyse it
  - Too much weight could even damage the blades
- The turbine blades must therefore be capable of preventing the formation of ice in order to guarantee their correct operation and ensure that they do not paralyse the generation of energy
- Coatings for ice melting that work as resistors which are heated by a electric current are available. As this kind of coatings consume energy, research works on passive antifreeze systems are being carried on.

Sources:
nanopatentsandinnovations.blogspot.com;
Windpower Engineering & Development;
Fraunhofer;
ACSNANO. *Liquid-Infused Nanostructured Surfaces with Extreme Anti-Ice and Anti-Frost Performance*

Focus

n

µ

Degree of maturity of the application

○ Potential application

- *The University of Harvard recently developed a solution incorporating nanotechnology which prevents the formation of ice*
- *General Electric, CG2 Nanocoatings, Luna Innovations and Seashell Technologies have developed an ice-phobic surface*

Micro/nano developments

- Hydrophobic nanocoatings
  - They imitate the lotus's hydrophobic surface
    - Recent papers claim that in lotus-based surfaces ice nucleation may happen faster than on smooth surfaces in the same highly humid conditions.
- Antifreeze nanocoatings
  - New techniques for the nanostructuration of surfaces with antifreeze effects
  - Biomimetic coatings based on antifreeze proteins
  - Carbon nanotube-based coatings to prevent ice formation
  - SLIPS-based materials (Slippery Liquid Infused Porous Surfaces). SLIPS are designed to expose a defect-free, molecularly flat liquid interface, immobilized by a hidden nanostructured solid. On these ultra smooth slippery surfaces fluids and solids alike (including water drops, condensation, frost, and even solid ice) can slide off easily
  - Solgel coatings microstructured via laser

Nowadays, research works on passive antifreeze are being carried on in order to avoid ice formation on blades without energy consumption

nanoBasque

1. Introduction
2. Methodology
3. **Micro/nano roadmap in offshore wind energy**
   - Key factors of offshore wind energy
   - Value chain of offshore wind energy
   - Micro/nano applications in offshore wind energy
   - **Positioning of Basque agents**
   - Challenges and opportunities to be taken advantage of
4. Micro/nano perspective in wave energy

Introduction

This chapter aims to identify the capacity and experience available from the different Basque science and technology offer agents to contribute, from the micro/nano field, to problem issues identified by developing off-shore wind energy.

The result is specifically shown from the following analysis

Identification of agents from the Basque scientific-technological offer with the capability to contribute to developing knowledge and technology in the field of micro/nano technology with potential application in the problem areas and challenges for the energy industry

General characterisation of the different agents, regarding type of RTD activity developed, areas of specialisation, etc.

Details of their positioning regarding skills and experience for each of the identified micro/nano applications in the industry.

Identifying agents with micro/nano capabilities in the Basque Country (1 of 2)

BERCs

CFM

- The Material Physics Centre is a research centre run jointly by the CSIS and the UPV/EHU
- Research into the chemical-physical properties of complex materials, electronic properties on a nano-scale, photonics and polymers and soft condensed matter

Basic data 2012

Foundation year: 2000*	Location: Donostia/San Sebastián
FTE researchers: 83	Director: Ricardo Díez Muiño

POLYMAT

- Groups together two complementary organisations: the Institute of Polymer Materials and the Basque Centre for Design and Macromolecular Engineering (BERC)
- Research into controlling the functional features and architecture of polymers, their interaction with inorganic and biological materials and the understanding of their three dimensional assembly (application in energy, electronics, transport, construction and biomedicine)

Basic data 2012 (BERC + Institute)

BERC foundation year: 2012 Inst. foundation year: 1999	Location: Donostia/San Sebastián
FTE researchers: 26	BERC director: José Mª Asua Inst. director: José Ramón Leiza

CICs

CIC nanoGUNE

- RTD centre for coordination, development and management of research work into nanosciences and nanotechnology in the Basque Country
- Research into nano-structures, nanomaterials and nano-structured materials, the development of nano-devices (electronics, spintronics, nano-magnetism and nano-photonics) and into biofunctional nanoparticles and nano-biotechnology

Basic data 2012 (physical CIC)

Foundation year: 2006	Location: Donostia/San Sebastián
Researchers: 62	Director: José Mª Pitarke

CIC microGUNE

- Centre for research and technological development into micro/nanotechnologies.
- Research revolving around electrochemical detection and immuno-magnetics of biological species, micro and nano-structuring of metals and polymers, nano-structured materials for detecting gases, microfluids, organic micro-optoelectronics and integrating micro/nanosystems

Basic data 2012 (all the CIC – virtual and physical)

Foundation year: 2004	Location: Arrasate/Mondragón**
FTE researchers: 76	Director: Nuria Gisbert

Sources: CFM, POLYMAT, CIC nanoGUNE and CIC microGUNE

(*) BERC consideration in 2008
(**) Physical CIC location

Identifying agents with micro/nano capabilities in the Basque Country (2 of 2)

Technological corporations

tecnalia Corporación Tecnológica

- This is a strategic alliance between Azti, Neiker and Tecnalia Research & Innovation resulting from merging 8 technology centres

azti tecnalia	Technology centre with expertise in marine and food research
neiker tecnalia	Public research and technological development institute in the agrifood and environment sector
tecnalia Inspiring Business	Private applied research centre resulting from the 2010 merger 8 different technology centres

Business Divisions

- Sustainable Construction
- Energy and Environment
- Innovation Strategies
- ICT – European Software Institute
- Industry and Transport
- Health
- Technological Services

Basic data 2012

Foundation year: 2001	Location: Donostia/San Sebastián*
FTE researchers: 1.382	Director: Joseba Jauregizar

IK4 Research Alliance

- Technological alliance made up of 9 technology centres

μ-n	ceit	Materials, applied mechanics, electronics and communications
μ-n	GAIKER	Plastics, composites, environment, assessment, biotechnology
μ-n, E	IK4 CIDETEC	Energy, surface treatments, new materials
μ-n	IK4 IDEKO	Tool machine and manufacturing technology
μ-n, E	IK4 IKERLAN	Mechanics, electronics, ICTs, microsystems and fuel batteries.
μ-n	IK4 LORTEK	Joining technologies
μ-n, E	IK4 TEKNIKER	Mechatronics, manufacturing technologies and microtechnologies
μ-n	IK4 AZTERLAN	Metallurgy and metal materials
	vicomtech	Multimedia technology

Technological Units

- Biotechnology and biomaterials
- Micro and nanotechnologies
- Environment and recycling
- Energy
- Industrial management and production
- Mechatronics
- Materials and processes
- ICT

Basic data 2012

Foundation year: 2005	Location: Eibar**
FTE researchers: 1.200	Director: José Miguel Erdozain

Sources: Tecnalia and IK4

μ-n *Activities in micro/nanotechnologies*   E *Activities in energy*

(*) Location of the headquarters

These agents act by themselves in different phases of the innovation cycle, ...

Type of activity

Type of agent	Micro/nano offer agents	Basic research	Applied research	Technological development
BERC	CFM	✓		
	POLYMAT	✓	✓	
CIC	CIC nanoGUNE	✓	✓	
	CIC microGUNE	✓	✓	
Tech. Corp.	Tecnalia		✓	✓
	IK4		✓	✓

RESULTS	Knowledge	→	Products / solutions
PERIOD FOR APPLICATION TO REACH MARKET	Long term	→	Short term

Markets / Applications

... have different specialisation profiles

	Techological specialisation		Sector-based specialisation
Micro/nano offer agents	**Micro**	**Nano**	**Energy**
CFM		●	
POLYMAT	◔	◑	◔
CIC nanoGUNE		●	
CIC microGUNE	●	◔	
Tecnalia		◑	◑
IK4	◑	◑	◑

... and they have the capability and wide-ranging experience in the micro/nano field to participate in developing offshore wind energy that we can classify into three levels

Criteria for classifying the level of capability and experience in micro/nano applications for offshore wind energy

●	***Experience and capability as part of the centre's core activity***	• It has micro/nano skills and knowledge (infrastructure, equipment, etc.) related to the application and it has experience in projects or lines of work that directly or indirectly tackle this problem • In addition, the application meets or forms part of a priority/core line of work for the centre, concentrating significant resources and keeping up a proactive attitude.
◐ (grey)	***Experience and capability within the centre's non core areas***	• It has micro/nano skills and knowledge (infrastructure, equipment, etc.) related to the application and it has experience in projects or lines of work that directly or indirectly tackle this problem • The application and its associated technologies do not feature among the centre's core priorities or activities, remaining more reactive in its participation in this field.
○	***Potential support capability, although no proven experience in the application***	• It has micro/nano skills and knowledge that might help to develop the application although it does not have any specific experience in projects related to the matter in question

... and they have the capability and experience in the micro/nano field to participate in developing offshore wind energy

Analysis of Basque scientific-technological agent positioning

Identified micro/nano applications	CFM	POLYMAT	CIC nanoGUNE	CIC microGUNE	Tecnalia	IK4
1. Combination of new structural materials					●	●
2. New materials better-balanced in terms of cost-performance		●			●	●
3. Solutions to prevent corrosion and fouling		○	○		●	●
4. Preventing degradation due to UV rays		●	○		●	●
5. Improved tribological systems			◉	◉	●	●
6. Sensors for monitoring blade condition	○			●		◉
7. Protection systems against impact of rays and fires		●			○	◉
8. Anti-radar systems						○
9. Solutions for analysis and reduction of noise and vibrations				○		◉
10. Coatings to improve resistance to erosion and wear			◉	◉	◉	●
11. Ice-phobic surfaces		●	○	◉	●	●

● Experience and capability as part of the centre's core activity
◉ Experience and capability within the centre's non core areal
○ Capability for potential support, although no proven experience in the application

CFM's capabilities are completely transversal as it is a very basic research centre; this capabilities available are related to nano-compound simulation and characterisation

POLYMAT has micro/nano activities and projects related indirectly with several applications

POLYMAT

Analysis of POLYMAT positioning

Identified micro/nano applications	Capability level	Capabilities available	Related micro/nano activities and projects
1. Combination of new structural materials			
2. New materials better-balanced in terms of cost-performance	●	• Preparation, characterisation and optimisation of properties (mechanical, electrical and thermal) of nano-compounds of thermoplastic polymers and carbon nanotubes	• Hybrid macro-molecular nanomaterials with specific properties targeting industrial applications – *Spanish Government's scientific research program* • Polymeric nanocompounds for engineering with optimised properties – *Basque Government's program for scientific & technological capacities development (Saiotek - NANOPROP)*
3. Solutions to prevent corrosion and fouling	○	• Binder synthesis for anti-corrosion paints	
4. Preventing degradation due to UV rays	●	• Synthesis of hybrid coatings with metal oxide nanoparticles with the ability to absorb UV radiation	• Extended service-life and improved properties of wood products through the use of functional nanoparticles in clear coating and adhesive systems – *FP7 NMP Small Project (WOODLIFE)*
5. Improved tribological systems			
6. Sensors for monitoring blade condition			
7. Protection systems against impact of rays and fires	●	• Synthesis of coatings and hybrid adhesives based on nano-clay	• Extended service-life and improved properties of wood products through the use of functional nanoparticles in clear coating and adhesive systems – *FP7 NMP Small Project (WOODLIFE)* • Technologies for producing waterborne polymer dispersion with complex morphologies – *Spanish Government's scientific research programme (Consolider)* • Nanostructured waterborne polymer films with outstanding properties – *FP6 NMP (NAPOLEON)*
8. Anti-radar systems			
9. Solutions for analysis and reduction of noise and vibrations			
10. Coatings to improve resistance to erosion and wear			
11. Ice-phobic surfaces	●	• Synthesis of super-hydrophobic and anti-icing coatings and surfaces	• Polymers for super-hydrophobic and ice phobic surfaces – *Provincial Council of Gipuzkoa's research programme* • Morphology control for waterborne icephobic coatings and nanostructured quantum dots containing particles – *Spanish Government's scientific research program*

● Experience and capability as part of the centre's core activity
◐ Experience and capability within the centre's non core areal
○ Capability for potential support, although no proven experience in the application

The main capability available is the small scale characterisation

CIC nanoGUNE
nanoscience cooperative research center

Analysis of CIC nanoGUNE positioning

Identified micro/nano applications	Capability level	Capabilities available	Related micro/nano activities and projects
1. Combination of new structural materials			
2. New materials better-balanced in terms of cost-performance			
3. Solutions to prevent corrosion and fouling	○	• Electronic microscopy • Basic electrochemical knowledge	
4. Preventing degradation due to UV rays	○	• Small scale capabilities	
5. Improved tribological systems	◐ (grey)	• Small scale characterisation	• *Working with outside groups*
6. Sensors for monitoring blade condition			
7. Protection systems against impact of rays and fires			
8. Anti-radar systems			
9. Solutions for analysis and reduction of noise and vibrations			
10. Coatings to improve resistance to erosion and wear	◐ (grey)	• Characterisation of coatings • Surface characterisation • Small scale characterisation	• *Preparing oxide/nitride coating* • *Working with outside groups*
11. Ice-phobic surfaces	○	• Small scale capabilities	

● Experience and capability as part of the centre's core activity
◐ (grey) Experience and capability within the centre's non core areal
○ Capability for potential support, although no proven experience in the application

CIC microGUNE's available capabilities are linked to tribology, sensors...

CIC microGUNE
Microtechnologies Cooperative Research Center

Analysis of CIC microGUNE's positioning (1 of 2)

Identified micro/nano applications	Capability level	Capabilities available	Related micro/nano activities and projects
1. Combination of new structural materials			
2. New materials better-balanced in terms of cost-performance			
3. Solutions to prevent corrosion and fouling			
4. Preventing degradation due to UV rays			
5. Improved tribological systems	◯ (grey)	• Nanotribological characterisation of silicon for use in MEMS. Non stick layers. Minimising friction in silicon-based MEMS • Molecular deposition in vapour phase (MVD) to minimise adhesive and friction between components in MEMS. Increase in the load capacity for silicon and metals. • Nano-structured PVD/CVD coatings	• Nanopatterning Emerging Methods – *FP6 IST* • Development of Lithography Technology for Nanoscale Structuring of Materials Using Laser Beam Interference – *FP6 IST (DELILA)* • Setting up a company dedicated to providing a lithography service through laser interference for specific applications – *Basque Government's scientific research programme (Etortek – REF5179)* • Linear position sensor for EGCR relief valve – *Basque Government's cooperation project (Intek Berri - REF5145)* • Rechargeable portable micro-feeder and communication system for micro-device applications – *Spanish Government's program for scientific & technological capacities development (Profit – REF5151)*
6. Sensors for monitoring blade condition	●	• Pressure/deformation/wear micro-sensors • Wireless communications	• Development of Lithography Technology for Nanoscale Structuring of Materials Using Laser Beam Interference – *FP6 IST (DELILA)* • Setting up a company dedicated to providing a lithography service through laser interference for specific applications – *Basque Government's scientific research programme (Etortek – REF5179)* • Linear position sensor for EGCR relief valve – *Basque Government's cooperation project (Intek Berri - REF5145)* • Rechargeable portable micro-feeder and communication system for micro-device applications – *Spanish Government's program for scientific & technological capacities development (Plan de Centros – PROFIT, REF5151)*

● Experience and capability as part of the centre's core activity
◯ (grey) Experience and capability within the centre's non core areal
◯ Capability for potential support, although no proven experience in the application

... and icephobic micro-structuring

CIC microGUNE
Microtechnologies Cooperative Research Center

Analysis of CIC microGUNE's positioning (2 of 2)

Identified micro/nano applications	Capability level	Capabilities available	Related micro/nano activities and projects
7. Protection systems against impact of rays and fires			
8. Anti-radar systems			
9. Solutions for analysis and reduction of noise and vibrations	○	• Infra-red micro-sensors	
10. Coating to improve resistance to erosion and wear (turbine structure)	◐	• Nano-structured PVD/CVD coatings	• Nanopatterning Emerging Methods – *FP6 IST* • Development of Lithography Technology for Nanoscale Structuring of Materials Using Laser Beam Interference – *FP6 IST (DELILA)* • Setting up a company dedicated to providing a lithography service through laser interference for specific applications – *Basque Government's scientific research programme (Etortek – REF5179)* • Linear position sensor for EGCR relief valve – *Basque Government's cooperation project (Intek Berri - REF5145)* • Rechargeable portable micro-feeder and communication system for micro-device applications – *Spanish Government's program for scientific & technological capacities development (Profit-REF5151)*
11. Ice-phobic surfaces	◐	• Icephobic micro-structuring and obtaining super-hydrophobic surfaces • Nano-structured PVD/CVD coatings	• Project specialising in sol-gel combined with Nanoimprint. • Development of Lithography Technology for Nanoscale Structuring of Materials Using Laser Beam Interference – *FP6 IST (DELILA)* • Setting up a company dedicated to providing a lithography service through laser interference for specific applications – *Basque Government's scientific research programme (Etortek – REF5179)* • Linear position sensor for EGCR relief valve – *Basque Government's cooperation project (Intek Berri - REF5145)* • Rechargeable portable micro-feeder and communication system for micro-device applications – *Spanish Government's program for scientific & technological capacities development (Plan de Centros – PROFIT, REF5151)*

● Experience and capability as part of the centre's core activity
◐ Experience and capability within the centre's non core areal
○ Capability for potential support, although no proven experience in the application

Tecnalia has capabilities in the form of knowledge and infrastructures...

tecnalia Corporación Tecnológica

Analysis of Tecnalia's positioning (1 of 2)

Identified micro/nano applications	Capability level	Capabilities available	Related micro/nano activities and projects

1. Combination of new structural materials
2. New materials better-balanced in terms of cost-performance
	●	• Knowledge and infrastructures
		  • Equipment for manufacturing nano-strengthened compound material components or using micro-capsules (self-healing nano-compounds)
		  • Equipment for casting light alloy components with nano-particles on a laboratory and preindustrial scale
		  • Equipment for physical-chemical nanostructures and function characterisation of nanomaterials
			• Nano-compounds for wind turbine blades, for example, nano-strengthening and micro-capsules
			• Developing aluminium matrix casting with low cost, high mechanical resistance, lightweight nanoloads

3. Solutions to prevent corrosion and fouling	●	• Knowledge and infrastructures
		  • Equipment to prepare protective coatings: wet (sol-gel, chemical conversion, electrodeposits, electroless, ionic liquids, etc.) and dry (PVD, CVD), etc.
		  • Equipment for physical-chemical characterisation plus in terms of behaviour to corrosion of nanomaterials, accelerated aging and in real conditions (exposure in different environments)
			• High power offshore wind turbine development – *Spanish Government's industrial research programme (Cenit - AZIMUT)*
			• *Project on Basque Government's industrial research programme (Etorgai - FLOTEK)*
			• Micro/nanomaterials for offshore applications: protection systems and corrosion behaviour studies – *Several private projects*

4. Preventing degradation due to UV rays	●	• Knowledge and infrastructures
		  • Equipment to prepare wet and dry coatings
		  • Equipment for physical-chemical and functional characterisation (behaviour when exposed to UV rays) Lab (accelerated aging) and in real conditions (exposure in different environments)
			• Aging due to exposure to UV rays of micro/nanomaterials – *Projects carried out and in force*
			  • The UV aging effect has been studied and combined with other factors (condensation, erosion, saline mist, temperature variation)

5. Improved tribological systems	●	• Knowledge and infrastructures
		  • Equipment on a pre-industrial scale for thermochemical treatment of steels used in the multiplier.
		  • Equipment on an industrial scale for coating components using thermal projection (nano-micro dust).
		  • Equipment on a semi-industrial scale for depositing (nano-micro) coatings and/or coatings nano-structured by PVD.
			• High power offshore wind turbine development – *Spanish Government's industrial research programme (Cenit - AZIMUT)*
			  • Plasma-assisted thermochemical treatments.
			  • Coatings (nano-micro dust) by means of thermal projection.
			  • Coating nano-structured by PVD

... in almost all micro/nano applications identified

tecnalia
Corporación Tecnológica

Analysis of Tecnalia's positioning (2 of 2)

Identified micro/nano applications	Capability level	Capabilities available	Related micro/nano activities and projects
6. Sensors for monitoring blade condition			
7. Protection systems against impact of rays and fires	○	• Equipment for manufacturing and characterising nano-compounds (conducting nano-materials)	
8. Anti-radar systems			
9. Solutions for analysis and reduction of noise and vibrations			
10. Coatings to improve resistance to erosion and wear	◐	• Knowledge and infrastructures • Equipment to prepare coatings and characterise materials that can resist erosion and wear.	• Development and characterisation (aging) of protection coatings – *Private projects*

11. Ice-phobic surfaces	●	• Knowledge and infrastructures
		  • Equipment to prepare (super)hydrophobic, nano-textured, polymer surfaces (e.g. polyethylene) with a carbon load for example, anti-fouling layers of polymers with low surface energy.
		  • Equipment to characterise the (nano-micro)materials, e.g. physical-chemical, topographical and functional characterisation, climatic chamber, etc.)
			• Development and characterisation of nano-topographies and layers of antifouling polymers – *Projects carried out and in force*

● Experience and capability as part of the centre's core activity
◐ Experience and capability within the centre's non core areal
○ Capability for potential support, although no proven experience in the application

IK4 has experience in almost all applications, particularly in developing materials, coatings...

IK4 Research Alliance

Analysis of IK4's positioning (1 of 3)

Identified micro/nano applications	Capability level	Capabilities available	Related micro/nano activities and projects
1. Combination of new structural materials	●	• Knowledge and infrastructures for: • New composites (micro/nano-strengthened, lightweight, organic based micro/nanocomposites with a high resistance/weight ratio and auto-repair capability, etc.) • Improving the steel micro-structure	• Dispersion of micro/nano loads in polymeric systems: • *Spanish Government's industrial research programme (Innpacto-ANCHORING)* • Development of autorepearing polymeric nanocomposites – *FP7 NMP (SHINE)* • Research line for strengthening composites: • With renewable nanofires – *FP7 ENVIRONMENT (EUCLIPSE)* • With microfibres – *Basque Government's industrial research programme (Etorgai-ASEGURA)* • Research line on composites with high mechanical properties: • Nanocomposites – *Basque Government's scientific research programme (Etortek- iNANOGUNE & NANOIKER)* • Nanocomposites for lightening – *Spanish Government's industrial research programme (AUTONANO)* • Development of new active and functional materials – *Basque Government's scientific research programme (Etortek-ACTIMAT)* • Research line on selecting materials and improving methods for manufacturing different blade sizes: • *FP6 NMP (ACTIVATION)* • *Spanish Government's industrial research programme (Cenit-ADDNANO)* • *Basque Government's industrial research programme (Etorgai)* • *Basque Government's product development programme (Gaitek)*
2. New materials better-balanced in terms of cost-performance	●	• Knowledge and infrastructures: • New composites (micro/nano-strengthened, lightweight, organic based micro/nanocomposites with a high resistance/weight ratio and auto-repair capability, etc.)	
3. Solutions to prevent corrosion and fouling	●	• Knowledge and infrastructures: • Anti-fouling/anti-corrosion coatings with micro/nanotechnologies: sol-gel (also combining with PVD and PEO), metal coatings by incorporating micro/nanocontainers that inhibit corrosion • Micro/nanostructuring of surfaces: by current pulses for metal and alloy coatings, by anodised Al, Ti processes to produce micro/nanoporous surfaces • Auto-repair paint with microcapsules	• Anti-fouling surfaces development – *FP 6 NMP (AMBIO)* • Micro/nanostructured surface development – *FP7 NMP (NANOCLEAN)* • Multi-functional materials development – *FP6 NMP (KMM-NoE)* • *Spanish Government's scientific research programme (Consolider-FUNCOAT & TUBOSOL)* • Auto-repair paints development for micro encapsulation techniques – *Spanish Government's industrial research programme (Cenit-TRAINER)* • *Basque Government's programme for scientific & technological capacities development (Emaitek)* • Anti-fouling coatings development – *Basque Government's product development programme (Gaitek-ECOFOULING)*

… and tribological systems,…

IK4 Research Alliance

Analysis of IK4's positioning (2 of 3)

Identified micro/nano applications	Capability level	Capabilities available	Related micro/nano activities and projects
4. Preventing degradation due to UV rays	●	• Knowledge and infrastructures: • Coatings that resist UV radiation improve through inorganic and hybrid micro/nano additives • Paint strengthened with CNT	• Research line on micro/nanocomposites with high resistance to UV rays • Organic mould composites with micro/nano additives – *FP7 NMP (SAFEPROTEX); Basque Government's industrial research programme (Etorgai)* • Development of micro/nanocomposites – *Spanish Government's industrial research programme (Cenit-INFINITEX)* • Development of new active and functional materials – *Basque Government's scientific research programme (Etortek-ACTIMAT)*
5. Improved tribological systems	●	• Knowledge and infrastructures: • Lubricants with nano-particles: with green lubricant MoS_2 nano-particles with nano-additives based on ionic liquids • Tribological systems of nano-composites with a low friction coefficient • Incorporating lubricants in micro/nanoporous structures of Al, Ti and Mg oxides • Coatings (metal, ceramic, polymeric) with high mechanical resistance: PVD coating (with HIPINS technology), ceramic coatings using EPD, immersion or sprayed; coating of metal composites with lubricant micro/nanoparticles • Micro/nanostructured surfaces: by means of laser, current pulses, modification of the surface micro/nanoroughness by electro-polishing	• MoS_2 nanoparticles-based lubricants development – *FP7 NMP (ADDNANO)* • Development of low friction coefficient nanocomposites – *Spanish Government's industrial research programme (AUTONANO)* • *Basque Government's industrial research programme (Etorgai-NANO-4-CAR)* • Research line to develop micro/nano-coatings to improve the mechanical response: • Micro/nanocomposite coatings – *FP6 NMP (ACTIVATION)* • *Functional nano-coatings – Marie Curie (MILUBES); Spanish Government's scientific research programme (Consolider-FUNCOAT); Basque Government's programme for scientific & technological capacities development (Emaitek)* • Nano-coatings with high mechanical qualities – *Basque Government's industrial research programme (Etorgai-AUTOKONPON)* • Micro/nanocoatings with auto-repair capability – *internal projects* • Multi-functional materials development – *FP6 NMP (KMM-NoE)* • Research line on micro/nanostructured surfaces development: • Micro/nanostructured surface development – *FP7 NMP (NANOCLEAN)* • *Basque Government's programme for scientific & technological capacities development (Emaitek)*
6. Sensors for monitoring blade condition	○	• Knowledge and infrastructures: • Developing optical fibre sensors: Fibre operation and patterning to monitor composites, optical fibre coated with sol-gel • Composites / paints with electrical response by means of conducting micro/nano-loads	• Formulation and characterisation of conducting materials and coatings – *Basque Government's programme for scientific & technological capacities development (Saiotek-NANOACTIVE)* • Formulation and characterisation of conducting nanocomposites – *FP7 NMP (SAFEPROTEX)*

... except in the case of anti-radar systems

IK4 Research Alliance

Analysis of IK4's positioning (3 of 3)

Identified micro/nano applications	Capability level	Capabilities available	Related micro/nano activities and projects
7. Protection systems against impact of rays and fires	◎	• Knowledge and infrastructures: • New coatings: sol-gel coatings with surface micro/nanostructuring and with fireproof micro/nano-additives • Organic/inorganic hybrid surfaces with micro/nano-structuring by laser and/or incorporating nano-particles • Paints with micro/nano-additives: flame retardant micro/nano-additives, conducting micro/nano-loads • Composites with micro/nano-additives: fire resistant micro/nano-additives, conducting micro/nano-loads	• Formulation and characterisation of micro/nanocoatings with high fire resistance – *FP7 NMP (POLYFIRE & FIRE-RESIST)* • Conducting materials and coating formulation and characterisation – *Spanish Government's industrial research programme (ELECTROCLAY)* • Development of organic micro/nanocomposites with electrical properties – *Spanish Government's industrial research programme (Cenit-INFINITEX)* • Development of new active and functional materials – *Basque Government's scientific research programme (Etortek-ACTIMAT)* • Development of nanoadditive paints with fireproof properties – *Basque Government's industrial research programme (Etorgai-MODUL EGITURA)*
8. Anti-radar systems	○	• Paint strengthened with carbon nanotubes	
9. Solutions for analysis and reduction of noise and vibrations	◎	• Knowledge and infrastructures: • Development of MEMS and analysis based on MEMS for oil and vibrations • Modification of the surface micro/nano-roughness using electro-polishing	• Advanced lubrication by friction and noise reduction • Sol-gel coatings to alleviate noise • Advanced sensors
10. Coating to improve resistance to erosion and wear (turbine structure)	●	• Knowledge and infrastructures: • Micro/nano-strengthened polymeric composites • Paint with auto-regenerative micro/nano-additives and erosion resistant • Metal coatings: micro/nano-structured, with hard micro/nanoparticles	• Auto-repair materials – *Spanish Government's industrial research programme (Cenit-TRAINER)* • *Basque Government's programme for scientific & technological capacities development (Emaitek)* • *Basque Government's product development programme (Gaitek)*
11. Ice-phobic surfaces	●	• Knowledge and infrastructures: • Hydrophobe nano-structured surfaces • Hydrophobic sol-gel nano-coatings	• Development of icephobic nano-coatings for wind power – *Spanish Government's programme for scientific & technological capacities development (Profit)* • Hydrophobic nano-structured surfaces – *FP7 NMP (NANOCLEAN)*

● Experience and capability as part of the centre's core activity
◎ Experience and capability within the centre's non core areal
○ Capability for potential support, although no proven experience in the application

nanoBasque

1. Introduction

2. Methodology

3. **Micro/nano roadmap in offshore wind energy**
   - Key factors of offshore wind energy
   - Value chain of offshore wind energy
   - Micro/nano applications in offshore wind energy
   - Positioning of Basque agents
   - **Challenges and opportunities to be taken advantage of**

4. Micro/nano perspective in wave energy

Micro/nanotecnology may contribute to overcoming the main challenges of offshore industry…

Offshore industry's challenges	Micro/nano applications	Potential contribution level of micro/nanotechnology	Basque scientific & technological offer's capacity level
Reduced production costs	1. Combination of new structural materials	◔	●
	2. New materials offering greater cost/behaviour balance	◕	●
Reliability and extended useful life of the components	3. Solutions to prevent corrosion and fouling	◕	●
	4. UV degradation prevention	◕	●
	5. Improved tribological systems	◕	●
	10. Coating to improve resistance to erosion and wear (turbine structure)	◕	●
	11. Ice-phobic surfaces	◕	●
Remote monitoring and diagnostics	6. Sensors for monitoring blade condition	◔	◉
Safety and integration with the environment	7. Protection systems against impact of rays and fires	◑	◉
	8. Anti-radar systems	◑	○
	9. Solutions for analysis and reduction in noise and vibration	◔	◉

The Basque Country has a scientific & technological offer with capacities and experience supporting companies, specially in those applications related with the increase in reliability and useful life of components, which is where micro/nanotechnologies can make their largest contribution

nanoBasque

In order to increase the incorporation of micro/nano solutions among the Basque offshore industry, several conditioning factors have to be considered…

Market barriers and needs

Companies do not demand micro/nano solutions, but rather competitive solutions with the most adequate technologies

Micro/nanotechnology solutions are often more expensive than other alternatives. This is an important barrier in a sector where the cost reduction is the main competitive factor

Investment on micro/nanotechnology must be assessed with a long-term view taking into account the additional functionalities given and the savings generated

Micro/nano applications in offshore wind energy

Blades and multiplier are the parts of the turbine with the greatest potential in the incorporation of micro/nano solutions. Nevertheless, other key factors such as the problems related to marine environment (i.e. corrosion, abrasion, fouling) have a generalized impact over all components of the turbine.

Micro/nano value chain and S&T capabilities

Industrial base with many potential micro/nanotechnology users, but with the need of further development in the below links of the value chain, which are the ones directly related to micro/nano industry (intermediate applications and micro/nano raw materials providers)

Micro/nano solutions' contribution is concentrated on the field of materials where large scientific & technological capacities exist in the Basque Country. Nowadays, these capacities are ahead of companies demands.

There is a great potential for taking advantage of horizontal capacities and advanced micro/nano facilities of the most scientific research centers (CFM and CIC nanoGUNE) that, until now, have never been focused on this kind of activities

… and their cost competitiveness must be valued over other alternatives by the industry

These conditioning factors lay down specific guidelines on nanoBasque Agency's role

nanoBasque Agency's role

Spreading the micro/nanotechnologies' potential of addressing offshore energy generation systems' challenges, specially the wind energy's ones

Activating the demand of micro/nano solutions of offshore companies:

- Spreading the knowledge about Basque agents that are able to contribute in the research and development of solutions
- Prioritizing the application areas in which different companies are interested (i.e. solutions to prevent corrosion and fouling)
- Taking advantage of the boosting effect of integrator enterprises and intermediate agents such as the Energy Cluster

Boosting the creation of a specialized Basque sector in micro/nano (integrating nano/microtechnology to the products of existing coating companies and creating material supply enterprises) so this new sector can take advantage of these kind of activities in offshore market and can complement the value chain

Fostering the collaboration among Basque scientific & technological offer's agents in order to optimize their capacities supporting companies

Promoting the launching and the development of R&D projects

… of boosting micro/nanotechnologies

nanoBasque

1. Introduction
2. Methodology
3. Micro/nano roadmap in offshore wind energy
4. **Micro/nano perspective in wave energy**

Offshore wind energy and wave energy are connected through their value chains…

Basic structure of common components in offshore energy farms (wind and wave)

Energy harnessing system

	Wind turbine	Wave power converter
Structural elements	Tower, rotor hub, nacelle housing	Specific elements depending on the kind of converter used
Energy harnessing	Blades	
Mechanical conversion	Multiplier and powertrain	
Electrical conversion	Generator, converter, transformer	
Ancillary systems	Pitch, Yaw, Brakes, Safety	

Anchorage and signage systems

- Foundations and substructures
- Beaconage

Power grid connection system

- Submarine cable, connectors
- Offshore and onshore T&D equipment

Remote control

- Remote control

… which, at first level, share a common components structure

... and the evaluation of the applicability of offshore wind energy's guiding factors/milestones to wave energy...

Results from offshore wind energy

Key factors	Milestones	Applicability to wave energy
Reducing manufacturing costs	New materials replacing steel	High
	New materials to reduce blade costs	Medium
	Reducing weight	High
Reliability and longer useful lifespan for components	Extending wind turbines' useful lifespan	High
	Avoiding corrosion and fouling	High
	Avoiding adverse abrasion conditions and minimising maintenance	High
Remote monitoring and diagnosis	Picking up turbine condition information	High
Economies of scale	Increase in size of blades and rotor	Low
Optimising energy conversion and transmission	Bearing to reduce losses through friction	High
	Lubricants to reduce losses through friction	High
	New transmission systems	Medium
	Power electronics and generators that operate at medium voltage	Medium
Integration in the grid	Implanting storage systems (*)	High
Security and integration with the environment	Lightning protection systems	Low
	Fire protection systems	Low
	Minimising interference	Medium
	Reducing and analysing operational noise and vibrations	Medium

(*) See roadmap for the micro/nano technology application in Energy Storage

... which can transfer results obtained from analysing offshore wind energy to the wave energy field...

Basic common structure for offshore infrastructure components (wind and wave)

			Energy harnessing system (wind turbine / wave power convertor)								Ancho-rage and signage systems	Power grid connec-tion system	Remote control
			Structural elements			Energy harnessing	Mechanical conversion	Electrical conversion	Ancillary systems				
Key factors	**Milestones**	**Applicability to wave energy**	Tower	Hub	Nacelle structure	Blade	Multiplier & powertrain	Electrical system	Ptich & yaw systems	Breaking & security system	Foundations & substructure	Grid connection	Remote control
Reducing manufacturing costs	New materials replacing steel	High	1								1		
	New materials to reduce blade costs	Medium				2							
	Reducing weight	High			2	2							
Reliability and longer useful lifespan for components	Extending wind turbines' useful lifespan	High	3, 10	3, 9	4, 7, 10	3, 4, 7, 9, 10, 11	5, 9	3	5, 9		3, 10	3	
	Avoiding corrosion and fouling	High	3	3		3		3			3	3	
	Avoiding adverse abrasion conditions and minimising maintenance	High			10	10	5		5				
Remote monitoring and diagnosis	Picking up turbine condition information	High				6				6			6
Economies of scale	Increase in size of blades and rotor	Low				2							
Optimising energy conversion and transmission	Bearing to reduce losses through friction	High					5		5				
	Lubricants to reduce losses through friction	High					5						
	New transmission systems	Medium					x						
	Power electronics and generators that operate at medium voltage	Medium						x					
Integration in the grid	Implanting storage systems *(See roadmap for the micro/nano technology application in Energy Storage)*	High										x	
Security and integration with the environment	Lightning protection systems	Low				7							
	Fire protection systems	Low			7	7							
	Minimising interference	Medium				8							
	Reducing and analysing operational noise and vibrations	Medium			9	9	9						

nanoBasque

… making possible a first identification of micro/nano contribution in the wave energy field

Micro/nano applications	Applicability to wave energy
1. Combination of new structural materials	High
2. New materials offering greater cost/behaviour balance	High
3. Solutions to prevent corrosion and fouling	High
4. UV degradation prevention	High
5. Improved tribological systems	High
6. Sensors for monitoring blade condition	High
7. Protection systems against impact of rays and fires	Low
8. Anti-radar systems	Low
9. Solutions for analysis and reduction in noise and vibration	Medium
10. Coating to improve resistance to erosion and wear (turbine structure)	Medium
11. Ice-phobic surfaces	Medium

Appendices: Basque agents

The Material Physics Centre is a research centre run jointly by the CSIS and the UPV/EHU

Basic information

Organisational structure

Board of Directors

CFM Board | **Scientific committee**

Administration | Technical service

Lines of research

Physical-chemical aspects of complex materials	Electronic Properties at Nanoscale	Photonics	Polymers and soft materials

- Board of Directors: director, deputy director and general secretary
- CFM Board: Board of Directors, the coordinator for each line of research and representatives from the administration and technical services
- Scientific committee: scientific staff (CSIC and UPV/EHU)

Basic data 2012

Foundation year: 2000*	Location: Donostia/San Sebastián	Index. publications.: 186
FTE researchers: 83	Director: Ricardo Díez Muiño	Conferences: 113
R&D budget: 4M€**	Granted patents: 1	Thesis: 7

Source: CFM

(*) BERC consideration in 2008
(**) Executed budget

Scientific-technological specialisation

Research lines

Physical-chemical aspects of complex materials	• Theoretical and experiment line on structural and electronic properties of complex nano-structured materials. It aims to understand the properties and formation of nano-structured auto-assembled surfaces and other types of nanostructures.
	• Sub-lines:
	  • Modelling and simulation
	  • Spectroscopy and microscopy at nano-scale
	  • Gas/solid interfaces

Electronic Properties at Nanoscale	• Entirely theoretical line focussed on electronic properties of solids, surface and low dimensionality systems
	• Sub-lines:
	  • Electronic excitation on surfaces and nano-structures
	  • Nano-bio spectroscopy and ETSF
	  • Systems of correlated atoms and electrons, superconductors and superfluids

Photonics	• Study of the interaction between radiation and matter:
	  • Interaction between the light with metal nano-structures and semi-conductors to confine electromagnetic fields on a nano-scale
	  • Optical properties of new materials and elements and design of new photonic structures that provide laser confinement for bioimaging
	• Sub-lines:
	  • Nano-photonics
	  • Laser physics and material photonics

Polymers and soft materials	• Research that combines theoretical, experimental and simulation forces to get a fundamental understanding of the interaction between structures and dynamics on different scales of dimension and time (micro, nano, meso, macro) in systems with growing complexity based on polymers and soft materials, particularly multi-components and nano-structured and biopolymeric materials

This groups together the Institute of Polymeric Materials and the Basque Centre for Design and Macromolecular Engineering

POLYMAT

Basic information

Organisational structure

Polymeric Material Institute
Activity aimed at stimulating the relationship between industry and university in the field of polymers

POLYMAT

Basque Centre for Design and Macromolecular Engineering (BERC)
Basic research focussed on synthesis, assembly and processing polymers by means of combining theory and simulation

Both centres will be known as POLYMAT to the outside world, but their activities and management is differentiated. The institute depends exclusively on the UPV/EHU whilst the BERC is a foundation where the UPV/EHU also sits on the board alongside the Basque Government.

José Ramón Leiza (director of the Polymeric Materials Institute), nanoBasque (8/11/2012)

Basic data 2012 (BERC + Institute)

BERC foundation: 2012 Inst. foundation: 1999	Location: Donostia/San Sebastián	Index. publications.: 56
FTE researchers: 26	BERC director: José Mª Asua Institute director: José Ramón Leiza	Conferences: 103
R&D budget: 3M€*	Patents applied: 6	Thesis: 5

Source: POLYMAT

(*) Executed budget

Scientific-technological specialisation

BERC research units

Polymerisation processes	• Basic research to understand relevant polymerisation processes for industry, above all polymerisation in dispersed media
Nanobio-separations	• Developing tunable, versatile and high selective interfaces
Molecular and supramolecular materials	• Developing the chemistry and the auto-assembly of flat and curved polycyclical aromatic materials (e.g. acenes, fullerenes, carbon nanotubes and graphene) doped with heteroatoms
Polymers for biomedical applications	• Synthesis and characterisation of hard, hybrid and soft nano-particles for bio-applications • Coloidal and polymeric characterisation of bionanoparticles • Modelling heterogeneous polymerisation processes to produce hard, hybrid and soft nano-particles for bioapplications • Preliminary in vitro bioapplications by means of hard, hybrid and soft bio-nanoparticles

Polymeric Materials Institute lines of research

Polymerisation process	• Basic research to understand relevant polymerisation processes for industry, above all polymerisation in dispersed media
Processing polymers	• Research into the relationship of the structural properties and processing of polymeric materials (new polymeric mixtures, super-tough mixtures, new nano-composites, nano-composites based on polymeric mixtures and super-tough nano-composites)
Polymer science	• Study of hybrid systems of polymer-solvent, polymer-polymer and polymer-inorganic particles
Rheology	• Basic and applied research into polymers and polymeric composites that contain nano-particles revolving around the correlation of structures, rheology and properties. Occasionally, rheology for non polymeric dispersions is also researched

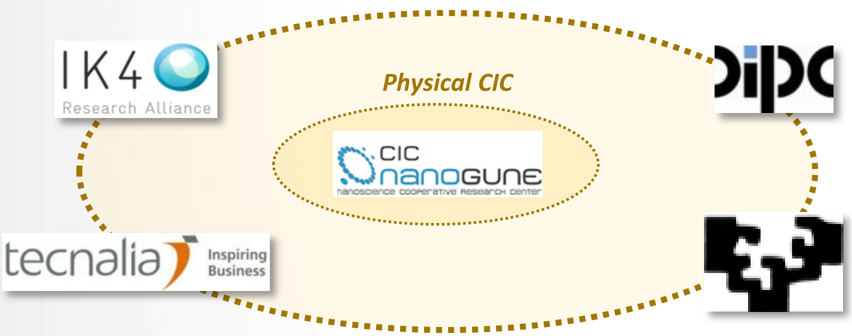
RTD centre for coordination, development and management of research work into nanosciences and nanotechnology

Basic information

Aims of CIC nanoGUNE

- Leading, supporting and coordinating research into nanosciences and nanotechnology in the Basque Country
- Promoting technology transfer and development of industry based on nanotechnologies
- Promoting the development of researchers who are highly qualified in nanosciences and nanotechnology
- Boosting joint projects and alliances between entities and regions internationally
- Strengthening the social use of research and scientific dissemination

Virtual CIC structure



Basic data 2012 (physical CIC)

Foundation year: 2006	Location: Donostia/San Sebastián	Index. publications.: 86
Researchers: 62	Director: José Mª Pitarke	Conferences: -
R&D budget: -	Granted patents: 1	Thesis: -

Scientific-technological specialisation

Strategic research areas

- Physics of small dimension structures, nanostructures and complex systems of structure in nanoscale
- Synthesis, assembly and nanomanufacturing of nanomaterials (nano-particles, nanotubes, fine layers, nanocomposites) and nanostructured materials
- Development of nano-devices and their impact on molecular electronics, spintronics, nano-magnetism and nanophotonics.
- Biofunctional nano-particles and nanobiotechnology

Research units

Nano-magnetism	Development of electronic nano-devices and their impact on magnetism, spintronics and molecular electronics.
Nanooptics	Optical near-field, optoelectronics, plasmonics, development of microscopic optical equipment and nanodevices and their effect on nanooptics
Auto-assembly	Synthesis and chemical functioning of nano-structures for assembly in nano-materials
Nanobiotechnology	Biofunctional nanostructures and nanotechnology
Nano-devices	Nano-structuring of systems by means of advanced lithography and layer depositing techniques
Theory of nanosytems	Theory and simulation of nanosystems
Nanomaterials	Synthesis and functioning of nanomaterials
Nanoimaging	Local microscopy and spectroscopy tests
Electronic microscopy	Cutting-edge infrastructure of electronics microscopy (includes TEM/STEM, Dual Beam FIB and ESEM.)

Source: CIC nanoGUNE

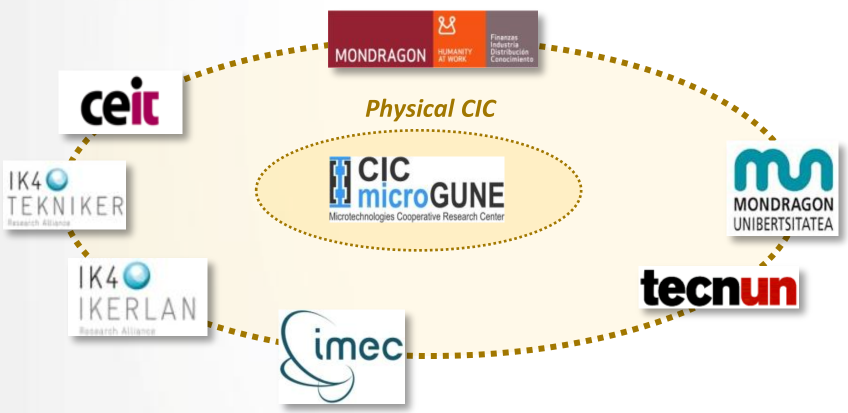
Research and technological development centre on micro and nanotechnologies

Basic information

Aims of CIC microGUNE

- Strengthening cooperation between different agents in micro/nanotechnologies by optimising the Basque Country's scientific-technological capability
- Developing international scale research in areas of micro/nanotecnologies
- Joining the European Research Area (ERA)
- Promoting technological transfer and convergence with other areas (biotechnology, ICTs, nanosciences) to develop emerging industrial sectors on the basis of convergence of these areas

Virtual CIC structure



Basic data 2012 (all the CIC – virtual and physical)

Foundation year: 2004	Location: Arrasate/Mondragón*	Index. publications: 176
FTE researchers: 76	Director: Nuria Gisbert	Conferences: 36
R&D budget: 5M€**	Granted patents: 2	Thesis: 4

Source: CIC microGUNE

(*) Physical CIC location
(**) Executed budget

Scientific-technological specialisation

Strategic research areas

- Electrochemical and immuno-magnetic detection of biological species
- Micro and nano-structuring of metals and polymers
- Micro-actuation on polymers
- Organic microoptoelectronics
- Nano-structured materials for gas detection
- Integration of micro / nanosystems

Research units

Microsensors	• Specialised in thin film and sensorisation • Focussing on electrochemical and immuno-magnetic detection for health applications and laser interferometric lithography (LIL)
Microfluidics and organic micro-optoelectronics	• Specialised in micro-components and packaging for fluid-based micro-devices • Micro-fluid technologies for lab on a chip for health applications • Organic microoptoelectronics for molecular photovoltaics and light emission microstructures
Micro / nanoengineering	• Specialised in micro-machining and ultra-precision techniques • Machining and nano-printing (NIL) for applications in fabric engineering, DNA stretching and protein chip

The Tecnalia Corporation groups together Azti, Neiker and Tecnalia Research & Innovation

tecnalia
Corporación Tecnológica

Basic information

Milestones

- **2001** Foundation of the Tecnalia Corporation
- **2003** Azti joins
- **2004** ESI joins
- **2006** Neiker joins
- **2007** Fatronik joins
- **2009** Merger is approved, Cidemco joins
- **2010** LEIA and EUVE join
- **2011** TRI works like an organisation

Business Divisions

- **Sustainable Construction**
- **Energy and Environment**
- **Innovation Strategies**
- **ICT – European Software Institute**
- **Industry and Transport**
- **Health**
- **Technological Services**

Basic data 2012

Foundation year: 2001	Location: Donostia/San Sebastián*	Index. publications.: 151
FTE researchers: 1.382	Director: Joseba Jauregizar	Conferences: -
R&D budget: 113M€**	Granted patents: 18	Thesis in 2012: 8

Source: Tecnalia

(*) Location of the headquarters
(**) Executed budget

Scientific-technological specialisation

Centres' scientific-technological specialisation

azti tecnalia	Technology centre with expertise in marine and food research
neiker tecnalia	Public research and technological development institute in the agrifood and environment sector
tecnalia Inspiring Business	Private applied research centre resulting from the 2010 merger between 8 technology centres

Micro/nano activities in Business Divisions

Sustainable Construction
Energy and Environment
Industry and Transport
ICT – European Software Institute
Health

→

Nanomaterials
Nanophotonics
Multiscale simulation
Environmental, Health and Safety

Technological alliance made up of 9 technology centres

IK4 Research Alliance

Basic information

Milestones

1963	Foundation of the first centre (CIT, currently CEIT)
2005	Strategic alliance
2006	Vicomtech and Cidetec join
2007	Ideko joins
2010	Lortek joins
2011	Azterlan joins

Partner technology centres

vicomtech, ceit, IK4 AZTERLAN, IK4 CIDETEC, IK4 TEKNIKER, GAIKER, IK4 LORTEK, IK4 IDEKO, IK4 IKERLAN

IK4 Research Alliance

Basic data 2012

Foundation year: 2005	Location: Eibar*	Index. publications: 176
FTE researchers: 1.200	Director: José Miguel Erdozain	Conferences: 36
R&D budget: 96M€**	Granted patents: 15	Thesis: 39

Source: IK4

(*) Location of the headquarters
(**) Executed budget

Scientific-technological specialisation

Centres' scientific-technological specialisation

μ-n	ceit	Materials, applied mechanics, electronics and communications
μ-n	GAIKER	Plastics, composites, environment, assessment, biotechnology
μ-n, E	IK4 CIDETEC	Energy, surface treatments, new materials
μ-n	IK4 IDEKO	Tool machine and manufacturing technology
μ-n, E	IK4 IKERLAN	Mechanics, electronics, ICTs, microsystems and fuel batteries.
μ-n	IK4 LORTEK	Joining technologies
μ-n, E	IK4 TEKNIKER	Mechatronics, manufacturing technologies and microtechnologies
μ-n	IK4 AZTERLAN	Metallurgy and metal materials
	vicomtech	Multimedia technology

μ-n *Activities in micro/nanotechnologies* E *Activities in energy*

Technological Units

- Biotechnology and biomaterials
- Environment and recycling
- Ind.management & production
- Mechatronics
- ICT
- Materials and processes
- Micro and nanotechnologies
- Energy

Micro and nanotechnologies

- Micromechanics
- Microoptics
- Microfluids
- Microelectronics
- Micromanufacturing
- Generating electrical micropower
- Synthesis and functioning of nanoparticles
- Synthesis of nanomaterials
- Nanolithography
- Nano-structured coatings
- Nanosensors
- Nanoelectrochemistry
- Ultra-precision systems
- Micrometrology
- Nanomedicine

Energy

- **Fuel cells**
- **Energy Storage**
- Distributed generation
- Combustion and thermal processes
- Solar energy
- **Wind energy**
- Biomass and biofuels
- Batteries
- **Super-condensers**
- Energy scavenging
- Hydrogen production and storage

nanoBasque