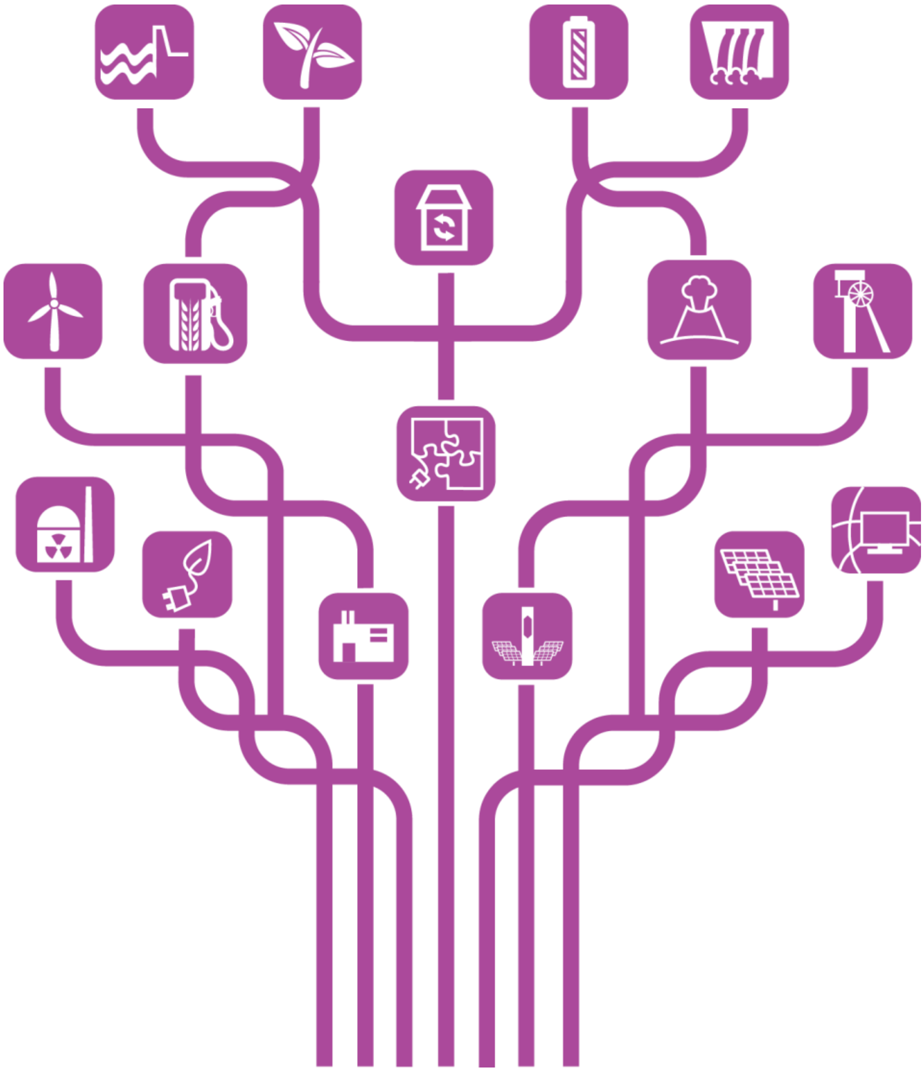
Strategic Energy Technology (SET) Plan

Towards an Integrated Roadmap:
Research & Innovation Challenges and Needs
of the EU Energy System

ANNEX I: Research and innovation actions

Part II – Competitive, Efficient, Secure, Sustainable and Flexible Energy System



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HEADING 1: Making Renewable Electricity and Heating/Cooling Technologies Competitive by 2020 and beyond

Challenge 1: Wind Energy

Wind energy is the renewable energy (RE) technology expected to provide the largest contribution to the RE targets. In 2013 there were 117 GW of installed wind energy capacity, enough to cover 8% of the EU's electricity consumption. By 2020 these figures could reach 216 GW and 14% of electricity demand and by 2030 350 GW installed could cover between 21 and 24% of demand[1].

KEY ISSUES

Production value chain performance/cost competitiveness

- Offshore wind needs to reduce its levelised cost of energy (LCoE) to 50% of 2010[2] levels by 2030, by increasing reliability and availability, by reducing costs from component to power production including through improved materials and advanced manufacturing capabilities, and by optimising logistics, installation, operation and maintenance. These improvements should enable an offshore capacity factor of 50% already by 2020.
- Onshore wind aims to reduce its LCoE by 20% in 2020 and by 30% in 2030, again with reference to the 2010 levels, and to enlarging the deployment possibilities. Focus will be on:
  - Developing innovative technologies adapted for complex terrains and with significantly reduced mass of turbine.
  - Turbine upgrade processes requiring new, increasingly sophisticated condition monitoring techniques to maximise the yields from existing wind farms.
  - Developing new foundation designs that are more suited for repowering.

Supply chain

- Achieve standardisation of component design, develop standards and create supply chains to produce turbines and components in grand volumes to generate economies of scale.
- Develop the infrastructure for the offshore sector, with the design and construction of dedicated ports and offshore logistic hubs.
- Develop effective methods for repowering and recycling.
- Develop lighter, stronger, cheaper materials which will extend the lifetime of wind turbine structures; these new materials should be suitable for appropriate recycling.
- There are certain turbine components or subcomponents, such as control and power electronics, which fail more often than it is desirable. More research is needed in why these components fail which findings should be applied into new, improved components.

System integration

- Electricity systems should allow higher wind power levels, up to 70% of the electricity demand, in an economic and safe manner.
- Ensure reliability of the grid at very high levels of wind power penetration by further improving system integration. Develop smart interfaces, new equipment capabilities, new or improved services to network operators (grid support services). Research in this area is a prerequisite for achieving high penetration for wind energy and will contribute to improved competitiveness. Standardised solutions will enable faster procurement for projects and therefore will reduce CAPEX.

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[1] 2013 Technology Map of the European Strategic Energy Technology Plan. doi:10.2790/99812

[2] The LCoE and reference year should be understood as the year of the final investment decision in a wind farm and its resulting LCoE

- Optimise coordination with network builders/operators to ensure timely connection to the grid.
- Wind power forecasting for power system operation should offer improved accuracy. For trading, a reduction of the day-ahead forecast error of 35%-45% by 2020 should be reached.

Wind conditions

- Improve the efficiency and accuracy of wind design conditions, siting, resource assessment and forecasting for onshore and offshore wind, taking into account different conditions, such as complex terrains and extreme climates.
- Developing an effective and standardised evaluation of uncertainty within each stage of the lifecycle of a wind project is a priority.

Non technological aspects

- Investigate and develop new market designs and optimal business models for a power system with high shares of non-dispatchable renewables (such as wind) generation, including efficient link to other energy markets, such as heat, coal, gas or transport fuels, also taking into account regulatory changes in public support schemes.
- Develop efficient market structures that enable high levels of wind deployment, by optimising e.g. energy market policy and administrative procedures.
- Develop a new model for the evaluation of wind energy vis-à-vis other energy technologies focused on the current and future impacts of the different technologies. An analysis that is based on scientific principles and that values the strategic, environmental, social and economic aspects of those technologies will help evaluating energy investments and illustrate clearly how wind energy contributes to a safe, secure, affordable, sustainable and environmentally friendly energy supply.
- Improved financing conditions for wind energy projects, especially reducing the cost of capital for offshore wind.
- Minimise the gap of qualified staff needed in STEM topics (science, technology, engineering and maths), related to wind energy.

Environmental and societal issues

- Develop knowledge on potential impacts of wind energy on the environment and develop techniques to minimise it. Compare the potential impact with other energy and non-energy technologies.
- Increase social acceptance and support for wind energy, especially onshore wind farms and repowering of old wind farms by investigating the motivation behind public opinion, reviewing case studies and best practices, improving public awareness of wind energy and environmental impacts and involving local communities.

ADVANCED RESEARCH PROGRAMME

Action 1: New turbines, materials and components

Scope: Developing cost-effective and reliable large turbines will contribute to making wind power fully competitive. This embraces from the development of cost-effective manufacturing processes for more performing materials to the scaling up of research projects, which often leads to the development of better or less expensive applications for smaller turbines in a cascading effect. Supporting these actions, therefore, contributes to the overall competitiveness of wind power.

To create the conditions for designing, producing and installing larger turbines. As a result, a number of prototypes of turbines between 10 and 12 MW should be installed and tested between 2017 and 2020.

Deliverables:

- Higher-performance steels, blade materials, permanent magnets etc.
- Low-maintenance power electronics and other components.
- Tested prototypes of 10-, 12- and 15-MW generators and drive trains.
- Tested prototype blades of up to 110m in length.

Expected impact:

- Significant reduction in cost of energy from wind farms using these machines.

- Increasing the efficiency of energy capture and the capacity factors of new turbines.
- Significant reduction in the number of wind turbines for a given wind farm capacity.
- Reduction in downtime from unplanned maintenance.
- Increase in the world market share of European wind turbine manufacturers.
- Development of a high-technology supply base in Europe.

KPIs:

- Prototype 10 MW generator and drive train by 2016; 12 MW by 2018; 15 MW by 2021.
- Prototype 100m blade by 2016 and 110m by 2018.
- 10 MW wind turbine in the market by 2018.

Costs: EUR 160 million.

Timeline: from 2015 - 5 years projects' duration.

Modality of implementation: Both European and national funding are necessary.

Action 2: Resource assessment – (Key issue: wind conditions)

Scope: One of the most important drivers for reducing the cost of energy is minimising uncertainty and improving the predictability and availability of wind energy production. A detailed knowledge of the climatic conditions (specially wind but also waves, ice, temperatures and so on) is fundamental for minimising investment risks; reducing financing costs from a reduction in resource assessment uncertainty; reducing cost of energy through lean turbine designs with less allowance for the uncertainty in climatic conditions; mitigating technical constraints and improving understanding of environmental constraints interacting with climatic conditions. An effective and standardised evaluation of uncertainty within each stage of the life cycle of a wind project is a priority. Cost competiveness of wind energy is closely linked to accurately quantifying uncertainty. It has an impact on the cost of finance and is therefore as important as the annual energy production (AEP) estimates.

Deliverables:

- Interaction flow on wind turbine generators (WTG) (single and in wind farms), comprising: Experimental campaigns.
- Ad-hoc models tailored to large rotors and large wind farms.
- Updated synthetic data for wind turbine codes.
- New standards, certification procedures and methodologies.
- Improved wake models both onshore and offshore quantifying loads and wake losses.
- Open platform for design condition models.
- Quantification of other extreme condition risks, comprising: Mapping of such conditions.
- Load measurements campaigns.
- Development of extreme condition standards.
- Mitigation strategies for extreme conditions.
- Uncertainty of yield and load prediction.

Expected impact:

- Improved standards and software for wind resource prediction and site assessment, including uncertainty evaluation, coupling both atmosphere-ocean and sea-land interactions.
- New knowledge in meteorological issues, applicable as well to other fields of science.
- Leaner, lighted wind turbines and components.
- Significant reduction in wake losses in wind farms.
- Increasing efficiency of energy capture and transformation.
- Reduction in downtime from ice and unplanned maintenance in particular in cold climate wind farms.

KPIs:

- Improve wind energy forecasts and understanding of wind conditions to develop predictions with an uncertainty of less than 3% by 2030.

Costs: EUR 70 million.

Timeline: from 2015 - 5 years project duration.
Modality of implementation: Both European and national funding would be suitable.

INDUSTRIAL RESEARCH AND DEMONSTRATION PROGRAMME

Action 1: Offshore technology – (Key issue: production value chain performance/cost competitiveness)

Scope: Short-to medium term research actions need to be addressed to allow the rapid deployment of offshore wind in Europe's waters. Focus should be on increasing reliability and availability of offshore wind turbines and their components; reducing cost of offshore wind from components to power production including through advanced manufacturing capabilities and developing infrastructure for the sector.
Make offshore wind power costs competitive with conventional electricity generation by 2030, develop technology in sites with a water depth beyond 50m and at any distance from shore.
Deliverables:

- Improved sensors and measurement technologies e.g. for extreme conditions.
- New bottom fixed substructures to minimise lifecycle costs.
- Improved offshore wind farm modelling techniques.
- Development and demonstration of WTG floating platforms.
- Development and validation of improved systemic WTG and substructure design models and practices.

Expected impact: -
KPIs:

- Cost of foundation EUR/MW/ water depth (m).
- Weight (mT)/ structure /MW installed.
- Quantification of operations costs and times for different floating structures concepts.

Costs: EUR 750 million.
Timeline: from 2016 - 4 years project duration.
Modality of implementation: Both European and national funding would be suitable.

Action 2: Logistics, assembly, testing, installation and decommissioning – (Key issue: supply chain)

Scope: Latest developments in onshore and offshore turbines with larger rotor diameters and new foundations required dedicated logistics infrastructures (ports, vessels, testing facilities).
The objective by 2020 is to achieve a serial large scale implementation of offshore wind with known technologies and achieve cost reductions by improving current methods.
Deliverables:

- New offshore installation processes.
- Definition of methods and standards for testing 10-15 MW wind turbine components.
- Improvement of size and capabilities of system-lab testing facilities for 10-15 MW turbines.
- Field testing facilities for 10-15 MW turbines aimed at increasing reliability.
- Development of five large scale manufacturing and logistics processes, both size and numbers for in and out-of-factory and site erection.
- Facilities, infrastructures and logistics for offshore wind:
  - New and better ports management strategies;
  - New and better vessels management strategies;
  - Improved installation methods and logistics
- Recycling and end-of-life scenarios.
- Turbine life-time extension and decommissioning.

KPIs:

- Installation of a 5MW-level offshore WTG and substructure at 230 EUR/kW by 2020.

- Speed of installation of offshore turbines and foundations reduced to 2 hours per MW-equivalent by 2018 (transport to site not included).
- EU methods and standards for testing large components (other than turbine components, which is treated in Action 1 of the Advanced Research Programme) available in 2015.

Costs: EUR 583 million.

Timeline: from 2015 - 5 years project duration.

Modality of implementation: Both European and national funding would be suitable.

INNOVATION AND MARKET-UPTAKE PROGRAMME

Action 1: Grid integration – (Key issue: system integration)

Scope: The successful transformation of the power system requires R&D and demonstration projects on connection technologies for offshore and onshore wind power plants to AC and DC networks (including multi-terminal HVDC grids); wind power capabilities for system support and virtual power plant (VPP) operation; and a better fit of wind energy in the power market.

To develop grid integration techniques enabling secure and cost-effective integration of high penetration levels of wind power; to develop and demonstrate optimal solutions for connecting offshore wind farms and clusters to future offshore networks; to develop and demonstrate methods for wind power management providing system support services with regard to market integration and combined operation with other power plants.

Deliverables:

- Demonstration of a multi-terminal offshore connection.
- The experience from existing HVDC-connected wind power plants is shared among the industry.
- Better wind plant modelling within electricity system models.
- Grid support services design and provision/VPPs.
- Testing of wind power plant capabilities (methods and facilities).
- Better knowledge of impact and operation of wind power on electricity markets.
- Improved wind power forecasting techniques and utilisation.
- Understanding of interaction between existing offshore wind farms and a future North Sea grid, including the definition of standards e.g. for connection.

Expected impact:

- Wind power will cover anywhere between 30% and 70% of electricity demand in an economic and safe manner.
- Better integration of existing offshore wind farms into a future North Sea grid.

KPIs:

- Multi-terminal offshore grids: efficiency of power collection (%); investment cost of power collection (EUR/MW); curtailment (% of yearly production); reliability (% availability); load factor of offshore grid (%).
- Grid support services: reliability of service (%); cost of service (EUR/MW or EUR/MWh); economic cost and benefit from ancillary services (EUR/MW and EUR/MWh); possible penetration (% on annual basis).
- Availability of data on HVDC connected wind power plants (%).

Costs: EUR 235 million.

Timeline: From 2015 - 2/3 years project duration.

Modality of implementation: Both European and national funding would be suitable.

Action 2: Spatial planning, social acceptance and end-of-life policies – (Key issue: non technological aspects)

Scope: to develop spatial planning methodologies and tools taking into account environmental and social aspects; to analyse and address social acceptance issues of wind energy projects including promotion of best practices; and to better define end-of-life options and policies including recycling.

Deliverables:

- EU offshore atlas capturing wind, wave, soil and bathymetry.
- Increased knowledge on noise issues (underwater, atmospheric propagation, monitoring and control, human perception of wind turbine noise).
- Assessment of the possible impact of wind turbine on health (noise, flickering/shadow, etc.).
- Development and validation of more accurate and robust noise propagation models.
- New passive and active aerial markings.
- Reduced local environmental impacts and increased environmental benefits (e.g. regarding birds, bats, fisheries, or the treatment of cumulative impacts).
- Improved siting and spatial planning techniques.
- Better offshore planning.
- Increased social acceptance.
- By 2018 a scheme will be consented to quantify/evaluate levels of acceptance/perception.
- Clearer guidance, methodologies and tools to assess the cumulative impact of wind farms in Europe.

Expected impact:

- Improvement of the social acceptance of wind energy in those areas (countries/regions/municipalities) where this was an issue.
- Improvement spatial planning regulations so that they do not limit technological developments, e.g. by imposing height limitations.
- Better knowledge of environmental and health impact of wind by individual and groups of wind farms.

KPIs:

- Consented guidance, methodologies and tools on assessment of cumulative impacts of wind farms in Europe should be developed by 2016.
- Rate of approval of new wind farm proposals reaching ten percentage points above current levels.
- Evaluation of offshore wind development costs.
- Cost optimisation measures identified.

Costs: EUR 15 million.

Timeline: from 2015 - 2 years projects duration.

Modality of implementation: Both European and national funding would be suitable.

Challenge 2: Photovoltaics

KEY ISSUES

- All major future important energy scenarios foresee key role for photovoltaic solar energy (PV). PV is renewable and has a huge global and European potential, making it an important building block for a secure and sustainable energy system. Even in the short term, i.e. by 2020, PV could cover as much as 10% of the EU electricity demand. This ambition provides the context for the RDI objectives:
  - Broadening cost-competitiveness of PV by RDI-driven technology improvements, enabling self-sustained growth under a suitable electricity market design.
  - Identification and development of solutions for large-scale integration of PV in energy grids and markets (see also Heading 2: Energy and System Integration).
  - Further improvements in quality, reliability and lifetime of PV components and systems.

  The RDI actions defined in this challenge address large-scale deployment of PV as well as seizing the related economic opportunities. The availability of world-class technology and advanced deployment solutions made possible through an ambitious innovation process is essential for the success of PV as a sustainable energy source, but also for the success of the European PV industry sector.

- Financial sector requirements for SHIP systems to become "bankable" for the financing sector and integrated into ESCO's portfolios; development of other financing and business models for SHIP technology dissemination.

Expected impact and KPIs:

- Integration of SHIP systems in industry energy audits by setting the preparation of a feasibility assessment of SHIP systems as an obligation in energy audits for industries with heat demand up to 250 °C.
- Effective public support policy for SHIP systems with first phase for low temperature and second phase for medium and high temperature SHIP systems (subsidy programs, interest reduced loans, renewable energy obligations, etc.).

Costs: EUR 30 million / public - 30%, private - 70% / initiatives assisting standardisation process, promoting regulatory requirements, promoting system monitoring concepts, promoting new/effective business models.

Timeline: 2014-2020.

Modality of implementation: European projects focused on development from TRL 9.

Challenge 5: Ocean Energy

KEY ISSUES

Production value chain performance/cost competitiveness:

Deliver technologies that: 1) generate effectively and reliably and 2) meet or exceed project investment criteria within supported markets. Achieve a LCOE target of <15-20EURc/kWh through the deployment of the first GW of wave or tidal stream technologies and associated cost reduction through volume, economies of scale and continued innovation. Continue on path to full competiveness with other low carbon options (<10EURc/kWh).

Supply chains:

Ensure a sufficient pipeline of project sites (>3-5GW in development by 2020) to encourage supply chain investment. Develop standards and standardise operating procedures, vessels, components and subsystems. Increase system lifetime, maintainability, reliability and accessibility offshore. Improve logistics and create supply chains for progressively larger projects. Make anticipatory investments in infrastructure such that grid links, ports and harbours are built in advance of projects.

System integration:

Ensure that the development of European grid infrastructure anticipates the use of large scale ocean energy. Ensure benefits from reduced system costs of integrating temporally diverse ocean energies with other renewables such as wind and solar are recognised and captured in decisions made about the energy mix and energy system investments. Investigate fuel production and energy storage options.

Non technological aspects:

Achieve a sustainable business model through technology advancement and market enablement measures for projects to generate a return on investment comparable with other investment opportunities (>8%-15%). Ensure the availability of finance to match market demand and support for global uptake of European ocean technologies. Engage banking and insurance sectors to accelerate market uptake. Remove uncertainties from the potential environmental impact of ocean energy technologies to accelerate consenting.

Societal issues:

Ensure that the increase in knowledge and economic benefits associated with the advancement of ocean energies are recognised and factored into decision making. (eg benefits to remote communities, potential for skills transfer from fishing and other maritime activities, manufacturing benefits, potential for technology transfer to other sectors). Increase public awareness of ocean energy and share knowledge of impacts (or lack of impacts) on the environment to reduce consenting timelines.

Introduction to the Programmes:
While wave and tidal are at different stages of development, it is the opinion of the stakeholders that a common program for both should be maintained, as most issues are similar for both. The timelines are slightly different, as the Advance Research and the Industrial Research and Development programmes are more relevant to wave energy, given its TRLs; whilst the Industrial Research and Development and Market Uptake programmes are more relevant to tidal energy. That said, this is a general rule, but should not be applied systematically but rather on a project by project basis.
Additionally wave and tidal are only two of the existing ocean technology and splitting actions according to respective issues concerning OTEC and Salinity Gradient would add complexity.

ADVANCED RESEARCH PROGRAMME

Action 1: Site Characterisation
Scope: The aim of this action is to develop tools and know-how to the characterisation of:
- Resource: correct assessment of energy available, modelling of the capacity factor and uncertainties associated, and modelling of local phenomena (as turbulence) likely to drive the sizing of devices.
- Physical conditions: sea bed investigation, local current confines, site accessibility.
- Environment: seabed, wildlife and plant life characterisation and impact measurement.

Deliverables:
- Innovative hardware or methodologies; Improved modelling techniques; Best practices for data collection; Joint technological and environmental data collection; Data quality increase; Dissemination; Identification and suitability of resource types per technology.

Expected impact:
- Reduced time and cost for development applications, installation, operation, maintenance, reduced production uncertainty by 10 %; Cross-fertilisation with other sectors for universally valuable data and knowledge gathering.

KPIs:
- Increase towards 90-95% predictability of resources.
- Decreasing of development cost by identifying multi-scale sites confines.

Costs: EUR 10 million.
Timeline: 2014-2017.
Modality of implementation: -

Action 2: Technological Research – Devices, components, materials
Scope: Projects in this action should address the designs of basic components and subcomponents and realisation of a first demonstrator for primary technologies of marine energy devices:
- Power take-off.
- Prime-mover, electrical conversion, marine connectors and wires.
- Pooring technologies, drilling, anchoring.
- Installation procedures, vessels and marine technologies.
- Projects should also address fundamental topics, strongly related to marine industry issues, as:
  - Material sciences.
  - Chemistry (corrosion).
  - Hydrodynamics and fluid dynamics, including tank testing.
  - Electromagnetism.
- Projects should study the transfer of existing technologies to marine applications. Development of new technologies also requires relevant protocols for testing, prediction and analysis of load cases.

Deliverables:
- New component functionalities; transfer of existing technology to marine applications; Innovative materials for reduced weight, cost, improved strength and suitability for marine applications; supply chain standardisation.

Expected impact:

- Reduce costs towards the 15-20 c/kWh target (%); Increase yield and life-cycle reliability toward the 15-20 year lifetime target; reduce environmental impact; achieve design consensus on different technologies to unlock mass manufacturing.

KPIs:

- Reliability of the concept tested.
- Measurable cost reduction.
- Component standardisation.
- Environmental impact.
- Compared to similar existing technologies.

Costs: EUR 140 million.

Timeline: 2014-2017.

Modality of implementation: local project gathering technologies developers, utilities, and industrial partner.

Action 3: Grid services and inter-array interactions

Scope: Address the specific issues associated with the efficient, reliable transmission of electricity /energy produced by marine energy devices, alone or in arrays; analysis and design of a dedicated electrical distribution system valid for most devices/arrays; development of cost effective transformers, switch gear, dynamic cabling, connectors and static cabling suitable for the highly dynamic marine environment and on platforms that are most appropriate (e.g. floating, fixed, subsea). Test and evaluation of such components and systems, potentially integrated with action 1 of IR&D Programme and or with other complimentary technologies such as offshore wind.

Deliverables:

- Control algorithms for ocean energy array; smoothing of energy output over time; new electrical distribution systems; standardisation of connectors; umbilical inter-array cabling.

Expected impact:

- Reduce CAPEX linked to cabling; Grid stability services; Industry wide solutions; cable-laying in high energetic zones.

KPIs:

- Measurable reduced CAPEX in the complete chain.
- Standard connectors for 440V, 3KV and 11kV. DC cables.

Costs: EUR 50 million.

Timeline: 2014-2017.

Modality of implementation: -

Action 4: Array design and modelling tools

Scope: Creation of design tools to optimise array layout and understanding of device performance in arrays, independently of device used. Take advantage of the first prototypes of devices and small farms for validation of numerical models. Evaluate uncertainties in modelling. Develop models to determine balance between cost of array, its efficiency and the complexity of the proposed layout. Determine balance of plant for array control algorithms.

Deliverables:

- Design tools and initial analysis report on array design and performance.

Expected impact:

- Improved array performance, reduced cost of energy, industry-wide solutions.

KPIs:

- Decrease uncertainties by less than 10%.
- High array performances.
- Reduce array costs.

Costs: EUR 10 million.

Timeline: 2014-2017.
Modality of implementation: -

INDUSTRIAL RESEARCH AND DEMONSTRATION PROGRAMME

Actions under this programme are derived to encourage technology collaboration on subsystems and components to increase reliability and drive down capital costs of technologies. They have the following impacts:

- Ensure EU industrial leadership is maintained; technical learning.
- Cost of energy reduction; public and private investments triggered.
- Increased market confidence.
- Reduced project risk.
- Blue Growth through supply chain opportunities.
- Increased socio-economic benefits.

Some additional specific impacts are listed for each action below.

Action 1: Technology System Testing and Demonstration

Scope: System-level and device testing, at scale and full-scale operation (typically individual ocean energy converters in real sea test environment – novel concepts and iterations of existing, promising concepts). Focus on: materials and techniques to reduce capital costs, automated machine operation to increase yield; failure prediction and preventative maintenance; reduction in operational costs from wear, fatigue and bio-fouling; increased system reliability; efficient space utilisation, maximising site potential for ocean technologies.

Deliverables:

- Progress of ocean energy devices to TRL 6/7 and beyond; system-level demonstration for TRL progression, deployable within devices.

Expected impact:

- Reliable technology, Technical learning;
- Reduced cost of energy;
- Increased market confidence.

KPIs: Number of devices progressing through TRLs, assessed through benchmarking performance across the sector and against standards as these is developed:

- PTO efficiency and capacity factor to reach at least 25% by 2020.
- Increased operational hours.
- Availability >85%.

Costs: EUR 150 million.
Timeline: 2014-2017.
Modality of implementation: European wide cross-country collaboration.

Action 2: Demonstration of Marine Technology Access and Logistics

Scope: Vessels adaptation, innovative vessel design, as well as methodologies for efficient offshore operations, covering construction, operation and decommissioning and innovations to reduce infrastructure bottlenecks (eg ports and harbours). Reduction in time and cost in installation, connection and disconnection of machines; improved accessibility for maintenance; reduction in time and cost for maintenance activities.

Deliverables:

- Demonstration of cross-sector utilisation of existing assets, using innovation for adaptation to Ocean Energy; Demonstration of novel vessels (or supporting solutions) in ocean energy marine operations in period to 2020; integration with other maritime users, eg tracking and navigation.

Expected impact:

- Understand and reduce installation and O&M costs, time to devices; increase days of operability at sea.

KPIs:

- Installation and O&M costs.
- Time to devices.
- Increase days of operability at sea.

Costs: EUR 70 million.

Timeline: 2017-2020.

Modality of implementation: -

Action 3: Monitoring and Analysis of Technology Demonstrations

Scope: Ensuring technical, environmental and socio-economic results from technology demonstrations are captured and disseminated, in order to inform future technology design as well as address environmental considerations feed back into consenting and minimise uncertainties on ocean energy project impacts.

Deliverables:

- Measurement and analysis of key technical parameters across regions and projects in order to consolidate certification procedures and impact assessment knowledge. Establish database of parameterised ocean energy projects, incl. access for diverse stakeholder. Supporting a science based approach to baseline data gathering, avoiding unnecessary work and reducing costs.

Expected impact:

- Comparability of projects; optimised environmental and socio-economic impacts; Consolidate and reduce consenting time.

KPIs:

- Creation of Database.
- Nº of projects analysed.
- Formal engagement and contribution from MS / projects.
- Validation and evolution of assessment criteria for certification bodies and authorities.

Costs: EUR 10 million.

Timeline: 2014-2020.

Modality of implementation: -

Action 4: Pilot Project Support** - **up to 10 MW, or 3-5 units

Scope: Moving from single device prototype technologies, to multi-device small-scale pilot projects; prove deployment, operability and generation of devices beyond single unit tests. CAPEX assistance required to continue foster innovation, otherwise early arrays will reduce innovation in order to reduce risk.

Deliverables: -

Expected impact:

- Technology deployment and market confidence.

KPIs:

- Number of projects including MW installed deployed using this scheme across Europe and corresponding investment by the private sector.
- Operational hours.
- Installed capacity.
- Inwards investment.
- Technology progression (TRL).

Costs: EUR 150 million.

Timeline: 2017-2020.

Modality of implementation: -

Action 5: Pre-normative research for developing Industry Standards

Scope: Develop industry standards for both the testing and manufacturing of devices, components and subcomponents, taking account of existing IEC/IEA work on standards. Ensure the use of manufacturing readiness level for the engagement of supply chain and OEM at broader scale and reduce CAPEX.

Deliverables:

- Standards and guidance for device and component manufacturing, engagement, consolidation and wider acceptance of standardised procedure for testing of ocean energy technologies.

Expected impact:

- Trigger investments through increased confidence from standard implementation, consistency and safety.

KPIs:

- Number of standards developed, number of standardised components.

Costs: EUR 5 million.

Timeline: 2017-2020.

Modality of implementation: -

INNOVATIVE AND MARKET-UPTAKE PROGRAMME

Actions under this programme have the following impacts: Ensure EU industrial leadership; socio-economic benefits and blue growth; private investments triggered; reduced LCOE; increased technological and environmental learning; market confidence and therefore uptake.
Some additional specific impacts are listed for each action below.

Action 1: Early Commercial Array Deployment Assistance Scheme

Scope: Deployment of 10+MW Scale Projects; This Action is focused on moving beyond the earliest "Pilot Projects" (addressed in Action within Industrial Research and Demonstration), reduce risk of multi-device deployment through grant schemes building upon innovation (CAPEX assistance). This addresses new, scale of deployment issues and therefore innovation and additional enabling actions are required as projects move towards greater scale.

Deliverables:

- In the region of 5 – 15 Individual projects deployed with the generating capacity of 10 – 50MW in each case.

Expected impact:

- Technology deployment leading to reduced Cost of Energy; Greater volumes creating supply chain opportunities, economic growth.

KPIs:

- MW installed.
- Nº of individual projects achieving Final Investment Decisions.

Costs: EUR 500 million.

Timeline: 2017-2020.

Modality of implementation: -

Action 2: Grid Integration Assistance, on- and offshore

Scope: Financing electrical studies, focusing on the Integration of ocean energy technologies alongside other RES and non-RES, considering the unique aspects of ocean energy production characteristics concurrently with other forms of generation, from resource through to power take-off systems; Projects demonstrating this integration intention and capability should be supported through CapEx in line with innovation risk. Standardisation of grid access point for offshore RES (including offshore wind) and contribution to the development of smart grid.

Deliverables:

- Increased grid access options for ocean energy projects; understanding of grid services provided by ocean energy, through more efficient use of existing grid infrastructure, etc. Ocean energy-specific electrical system models. Stable grid-connected ocean devices.

Expected impact:

- Access to a wider range of sites; optimisation of EU integrated grid system.

KPIs:

- Number of MWs available in periphery of grid systems.
- Ocean Energy MWs able to connect through existing / shared connections with other generators.

Costs: EUR 15 million.

Timeline: 2014-2020.

Modality of implementation: -

Action 3: Establish consistent Consenting, Environmental and Socio-economic Assessment Baseline Frameworks

Scope: Determine a standard baseline state for several environmental areas impacted by ocean energy: benthos, marine life, sediments, etc. Develop scenarios for impacts at project level, as well as for the overall EU installed capacity. Streamline socio-economic impact assessments of ocean energy projects for consistent evaluation across at national and EU level.

Deliverables:

- Demonstrate co-ordination and consolidated output along with existing working groups and initiatives; National- and EU-wide consistent framework and regulations; Consistent analysis method for environmental impacts and associated uncertainties; Identification and increase of positive environmental Impacts: Established national- and EU-wide assessment method for socio-economic evaluation.

Expected impact:

- Optimised environmental impacts, increased level of social acceptance, and increased ocean energy contribution to economic growth. Improved mitigation measure to reduce potential impacts, increased level of social acceptance. Reduced conflict of use with other marine sectors.

KPIs:

- Number of MS systems subscribed to a given procedural system.
- Number of uncertainties reduced.
- Reduced time and cost of EIAs / consenting.
- Quantification of ecosystem values, quantification of ocean energy project economic value in MS and EU context.

Costs: EUR 15 million.

Timeline: 2014-2020.

Modality of implementation: European, MS and Regional level.

Action 4: Manufacturing and Production Advances/ Supply Chain - Est. Cost: EUR 100m

Scope: Enabling the move from early production requirements (< 5 units) to large-scale manufacturing through automation, mass-production techniques, optimised logistics, etc. in order to facilitate volume capability. This should focus on progression from bespoke practices to incorporation of reduced time and cost of automated processes where possible (e.g. material forming, assembly lines of drive-train, electrical or mechanical load testing, transportation of multiple devices, etc.).

Deliverables:

- Demonstrable migration to automated processes; improved quality control and supply chain opportunities; Evaluation of supply chain value; Training and skills.

Expected impact:

- Reduced cost and time of manufacturing and delivery per MW, increased economic opportunity for supply chain, ensure EU Leadership in the sector.

KPIs:

- Unit cost per MW.
- Manufacturing lead time.
- Production capacity of the entire supply chain.

Costs: EUR 100 million.
Timeline: 2017-2020.
Modality of implementation: -

Challenge 6: Geothermal Energy

KEY ISSUES

Geothermal power production has a substantial potential in Europe. Technology includes the geothermal steam plants in Iceland, Italy and Turkey, as well as the use of hot water in binary systems (also applied in Austria, Germany, France, and Portugal). The next generation geothermal technology enhanced geothermal systems - EGS, aims at overcoming the geological limits for current geothermal power sites and strives to make geothermal power an option almost anywhere in Europe. The potential towards 2050 is stated in the SRA of the Geothermal Technology Platform (2012) as 320 GW installed capacity world-wide, with about 90-100 GW in Europe. Considering the high load factor of geothermal power plants with an average of about 70-80 %, geothermal energy could provide 550-700 TWh of electricity per year.

Most geothermal power plants are capable (or can be made capable, by tuning the flow rate of the in-well production pumps) of responding to command from system operators to ramp output up and down on demand and thereby can provide the necessary flexibility to the electricity system.

Geothermal energy offers vast resources to cover demand for **heating and cooling**, with numerous technical options, ranging from supply to individual buildings using geothermal heat pumps to providing heat (and cold) for whole cities or city quarters through large district heating networks.

Key Issue 1: Deploy EGS technology and make competitive this technology. The short-term targets of this challenge should be to achieve an installed geothermal power capacity in Europe of >3 GW (of which 1.5 GW in EU27) by 2020, and aiming at >10 GW by 2030.

Key Issue 2: Keep production cost for electricity from geothermal resources low, by decreasing installation and operation cost of the power plants, by increasing longevity of installations, by optimising efficiency and power output.

Key Issue 3: Include geothermal power in grid-optimisation schemes, and use its advantages as a base load, flexible, sizable, controllable, and local resource (one of the few among renewables).

Key Issue 4: Enhance the current use of geothermal energy for heating and cooling by reducing cost of exploration, drilling and installation, by improving longevity of material and efficiency of operation. In particular with geothermal heating and cooling, non-technical issues like investor awareness, city planning, regulations concerning the resource, etc. can create substantial barriers against further deployment, and thus need to be addressed in priority. Also activities outside the realm of geothermal energy sensu strictu, like development in thermal storage and in (smart) thermal grids, are crucial to make full use of the geothermal heat resources.

ADVANCED RESEARCH PROGRAMME

Action 1: Improving deep geothermal well design and completion

Scope: The cost of drilling usually increases exponentially with depth. Well design has to target longer operative well life, optimisation of well delivery and productive/injective capacities, prevention of particle invasion and well/formation impairment, mitigation of corrosion and scaling problems, reduction of well maintenance and work-over cost. The well completion technology needs to be improved in order to fulfil these design goals.