Sustainable Energy Authority of Ireland

National Energy Research, Development & Demonstration Funding Programme

FINAL REPORT

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SECTION 1: PROJECT DETAILS

Project Title	Mooring Optimisation DEsign for LRD Systems (MODELS)
Lead Grantee (Organisation)	Dublin Offshore Technology
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	Name	**Organisation**
Project Partner(s)		
Collaborators		

Project Summary (max 500 words)
Floating Offshore Wind (FOW) is a maturing technology, with significant potential in the Irish market to support industrial scale deployment of offshore renewable energy and meet Ireland's Climate targets. The challenges for FOW in Ireland in deploying in aggressive offshore conditions need to be overcome, and the Load Reduction Device (LRD) is a key component in supporting build-out of cost-effective FOW and allowing locations with high wind resource to be viably delivered. Technological innovation and system optimisation is a critical opportunity impacting the effectiveness of FOW array design and farm development. The MODELS project develops a key mooring design and optimisation tool which will facilitate the route to market for the LRD by giving mooring designers globally the ability to rapidly optimise their systems with an integrated LRD. The project builds on years of product validation within the Irish marine ecosystem and supports the significant export potential of the LRD, in addition to delivering a pathway to reduced LCOE for the Irish FOW market. The project delivers a customer facing design tool. This is validated against existing product testing work and against project case studies within the Irish FOW market to deliver the complete techno-economic benefit of the technology.

Keywords	Floating Wind Moorings LCOE Design

SECTION 2: FINAL TECHNICAL REPORT

2.1 Executive Summary

Floating Offshore Wind (FOW) moorings are currently based on legacy technology from the Oil & Gas sector, with some developments in mooring line technology to allow more appropriate solutions to be deployed. The mooring systems for these FOW platforms require significant innovation to support the cost reduction needed to make FOW commercially competitive with other forms of energy. The opportunities for innovation in FOW mooring systems are significant and will play a major role in delivering step changes in project insurability and cost, both for the superstructures and mooring system itself.

The LRD is a subsea mooring component which controls and significantly reduces the forces acting on the platform, mooring line and anchor. The Dublin Offshore LRD design works to optimise mooring response stiffness by passively rotating with wave loading and delivering accurate and reliable control of the FOW platform station keeping. This enables cost reduction through cheaper mooring lines, smaller anchors, lighter platforms, reduced risks of system failure and increased WTG uptime. The impact of the LRD on the project requires careful consideration as the unit impacts the design, installation, financing, insurance, and operation of the farm. The reduction of mooring loads is achieved by the controlled compliance of the platform provided by the LRD. Project specific requirements guide the geometry and performance of the LRD, and therefore undertaking design for an Irish FOW site provides a key step forward in quantifying the benefit to Irish FOW and the impact on LCOE.

A key step on the route to market for the LRD is enabling mooring designers within the FOW industry to rapidly and accurately include the technology within their design and arrive at a procurement ready specification for the LRD based on optimisation of their specific system. By rapidly and accurately including the LRD in design, it allows projects to consider the LRD at an early stage within their planning and greatly increases the probability of the LRD being procured. The key objectives achieved in the course of this project are listed as follows:

1. Validate combined LRD and mooring system response, including multiple background mooring types (catenary, inclined-taut-synthetic, semi-taut).
2. Delivery of the Software to accelerate LRD mooring design integration.
3. Publication of the MODELS Design Manual to support MODELS end-users.
4. LRD Mechanical Design Automation to support rapid design delivery and pricing.
5. Validation of the MODELS Toolkit with detailed techno-economic case-studies for FOW farms within the Irish market.

The toolkit developed in the course of the project is freely available https://www.dublinoffshore.ie/technology and is being used by project designers in Europe, Asia and North America. The implementation of the technology within a floating wind farm has the potential to cut project mooring system capex by 30% thus expediting the development of the Irish floating wind market and its contribution to the goals of the Climate Action Plan.

2.2 Introduction to Project

Floating Offshore Wind (FOW) moorings are currently based on legacy technology from the Oil & Gas sector, with some developments in mooring line technology to allow more appropriate solutions to be deployed. However, the industry requires significant innovation to deliver the reduction in cost and risk required for the commercial build out of FOW farms, in particular for resource intense sites such as are common around the Irish coastline. The requirement to reduce LCOE for FOW is shown in Figure 1, and the approximate portion of cost attributable to mooring systems is presented in Figure 2. In addition, any measures which can reduce the volume of material required for a FOW project mooring spread will be advantageous in making Irish port and harbour infrastructure viable, which suffers from limited capacities relative to FOW requirements.

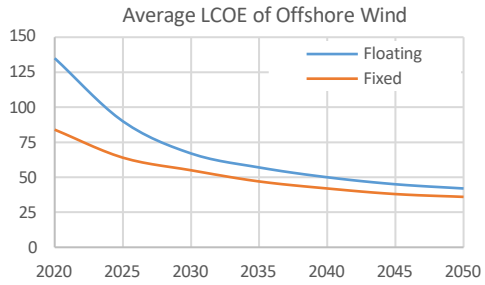

Figure 1 - LCOE reduction projections for Fixed and Floating Offshore Wind (DNV)

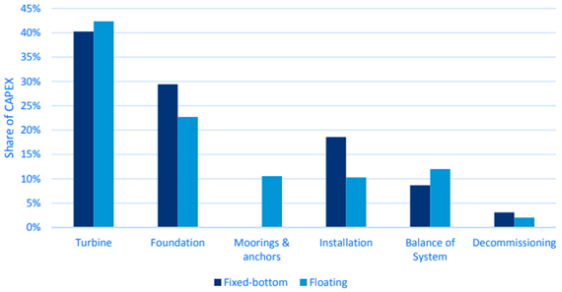

Figure 2 - Cost comparison between fixed and floating offshore wind projects (Carbon Trust)

The mooring systems for these FOW platforms require significant innovation to support the cost reduction needed to make FOW commercially competitive with other forms of energy. The opportunities for innovation in FOW mooring systems are significant and will play a major role in delivering step changes in cost both for the superstructures, insurability and mooring system itself. The introduction of non-linear compliance in a mooring line has been shown to result in significant reductions in mooring loads, resulting in validated benefits to the FOW system. The Load Reduction Device product development was initiated following a state-of-the-art review of the sector.

The LRD is a subsea mooring component which controls and significantly reduces the forces acting on the platform, mooring line and anchor. The Dublin Offshore LRD design works to optimise mooring response stiffness by passively rotating with wave loading and delivering accurate and reliable control of the FOW platform station keeping. This enables cost reduction through cheaper mooring lines, smaller anchors, lighter platforms, reduced risks of system failure and increased WTG uptime. The impact of the LRD on the project requires careful consideration as the unit impacts the design, installation, financing, insurance, and operation of the farm. The LRD is significantly developed as a component (TRL 7), with a track record of scaled demonstration and a Statement of Feasibility from independent certification body, DNV.

- **Connected in-line between anchor & platform**
- **Rotates with wave-induced platform motion**
- **Support local supply chain delivery**
- **Delivers controlled platform wave compliance**
- **25-year maintenance free performance**
- **Significant peak and fatigue load reduction**

LRD design is bespoke, scalable and iterative within validated hydrodynamically and aerodynamically coupled models integrating the overall FOW platform and Wind Turbine Generator behaviour for a system level analysis. Extensive physical testing of LRD based FOW systems has validated the numerical modelling tools – i.e. Orcaflex - to allow their use in detailed design and accurate calculation of mooring loads. Future work will include validation of all numerical modelling software currently available on the market, including DeepLines, SESAM, and MOSES.

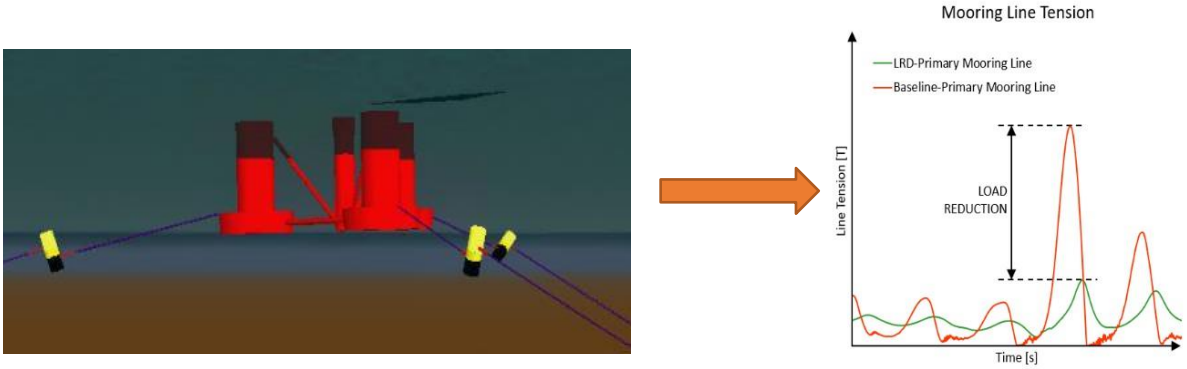

Figure 3: LRD Analysis and Mooring Force Reduction Calculation

The reduction of mooring loads is achieved by the controlled compliance of the platform provided by the LRD. Project specific requirements guide the geometry and performance of the LRD, and therefore undertaking design for an Irish FOW site will provide a key step forward in quantifying the benefit to Irish FOW and the impact on LCOE. The combination of the LRD mooring response and the background mooring response, as shown in Figure 3 provides an integrated mooring system which is uniquely optimised for project cost drivers.

A key step on the route to market for the LRD is enabling mooring designers within the FOW industry to rapidly and accurately include the technology within their design and arrive at a procurement ready specification for the LRD based on optimisation of their specific system. By rapidly and accurately including the LRD in design, it allows projects to consider the LRD at an early stage within their planning and greatly increases the probability of the LRD being procured. The development of the toolkit allows the LRD to be independently and accurately considered by global mooring designers without requiring ongoing direct and resource intensive support from Dublin Offshore. The toolkit efficiently leverages the LRD development and validation work undertaken to date to support product uptake by the industry.

2.3 Project Objectives

The primary objective of the project was to deliver to the Irish and global FOW industry a validated software design tool to support rapid and accurate mooring system optimisation. The Toolkit has been delivered with the supporting technical validation of the LRD performance encoded within the software. Project specific objectives are defined as follows:

#	Objective	Status
1	Validate combined LRD and mooring system response, including multiple background mooring types (catenary, inclined-taut-synthetic, semi-taut)	Complete
2	Delivery of the MODELS Software to accelerate LRD mooring design integration.	Complete
3	Publication of the MODELS Design Manual to support MODELS end-users.	Complete
4	LRD Mechanical Design Automation to support rapid design delivery and pricing.	Complete
5	Validation of the MODELS Toolkit with detailed techno-economic case-studies for FOW farms within the Irish market.	Complete

2.4 Summary of Key Findings/Outcomes

Innovation 1: Development of Mooring System Analysis Tool

A numerical model was developed using Python to simulate LRD-integrated mooring performance. The accuracy of the model was confirmed by comparing its results against data obtained from previously validated internal models, demonstrating a strong alignment between the Python-generated outcomes and those previously derived from Excel and Octave at the component level.

Additionally, the numerical model's performance was further evaluated by comparing its predictions with those generated by OrcaFlex, a sophisticated software used for simulating complex offshore systems. The comparison showcased a good level of agreement between the simplified approach used in Python and the more intricate calculations performed by OrcaFlex for a full mooring system, indicating the reliability and validity of the simplified models in approximating the behaviour of the LRD-integrated mooring system.

Innovation 2: Web-hosting of MODELS LRD Sizing and Specification

The MODELS analysis tool was written in python to support web hosting of the mathematical solver. The use of a web-hosted tool has many benefits including the ability to reach a wider audience including FOW decision makers who may not have access to costly licenses. Web hosting also ensures that new features and updates can be rolled out smoothly to ensure users benefit from the

latest simulations. In addition to the mooring designers having access to our tools on line, the user can download automatically generated LRD specification documents, and performance curves to verify behaviour in third party software.

Innovation 3: Automated CAD LRD Design

The MODELS project developed an automated LRD design tool to accelerate the LRD design and specification to improve engagement with both the supply chain and with customers. The LRD design automation process was implemented through a combination of numerical analysis in Excel and parametric product design in Autodesk Inventor. The design automation process reduces the time to deliver preliminary design engineering of the LRD from several weeks to several minutes thereby effectively eliminating the resource constraint as a bottleneck in our customer engagement journey.

2.5 Project Impact

The following impacts have been enabled as a result of the project activities and outcomes.

Category	Impact	Methodology	Timeframe	Impact
End User Impact	Power consumer: Reduced cost of electricity with greater integration of renewables within power generation mix	Validate lower project lifetime costs through detailed design, value engineering and cost validation with supply chain.	Year 2-4	On track
	FOW Developer: Reduced CAPEX and OPEX, and improved commercial viability for FOW	Validate lower project lifetime costs through detailed design, value engineering and cost validation with supply chain	Year 2-4	
Enterprise Impacts	Job Creation	The commercial success of the LRD will generate job creation for Dublin Offshore. High value technical roles will be created through the MODELS project, and with the subsequent roll-out of the LRD commercially.	Month 3 – Year 5	On track
	Irish Export Potential	The LRD is developed by an Irish company using Irish infrastructure and has the potential to play a major role in global FOW. The technology can be a key export for Ireland into the international FOW supply chain.	Year 2-4	
	Turnover Growth	The commercial success of the LRD will generate significantly increased turnover for Dublin Offshore through sales of the commercial product. Dublin Offshore will achieve profit through LRD sales to the Irish and global market. Revenue growth in parallel with productivity and market uptake is forecast to lead to yearly	Year 2-4	

		profitability before 2026.		
	Go To Market Strategy	Develop product specification through integration of parametrized LRD mechanical geometry linked to MODELS input. Development of GTM Strategy based on market expectations and preferred delivery model	Year 1	
	Increased Local Content for Irish FOW	Engagement with fabricators and supply chain. Include LRD within project Bill Of Materials for local fabrication budgeting. The LRD is fabricated from standard structural steel and concrete ballast delivered to standard industry tolerances Irish steel fabricators are well placed using existing capabilities. LRD fabrication up to 2050 would additionally require approximately 540,000 Tonnes of Irish steel-fabrication	Year 1-15	
Scientific	Data points for reduced LCOE for Irish FOW, supporting existing literature	Existing LCOE calculations for Irish FOW, such as undertaken for Eirwind, do not include the significant cost implications of LRD integration. The revised achievable LCOE with an LRD integrated system will provide new literature for academia and industry stakeholders to include in review when analysing the viability of Irish FOW.	Year 1	Achieved
Policy	Improved cost profile for demonstration of industry viability in support of accelerated regulatory approval, and geographical variation in Risk and Opportunity	The variation in the reduced LCOE which can be achieved through integration of the LRD may provide a different picture to policy makers of the value of particular projects and regions. It is important for realistic project potentials to be understood during consenting and regulatory engagement.	Year 1	Achieved

2.6 Recommendations

Please highlight any implications/opportunities/recommendations for Ireland (e.g., for policy makers, for the research community, for industry) based on the work carried out in the project.

1. Consider the acceleration of a Floating Offshore Wind Specific Offshore Renewable Energy Auction that will repair investor confidence in the Irish Offshore Wind Market.
2. Undertake an assessment of the Irish supply chain with respect to the requirements of Floating Offshore Wind farms of 1GW scale and provide enterprise supports for Irish SME's who are operating in the space.
3. Undertake an assessment of industry challenges that require solutions to unlock the potential for floating wind in Ireland - provide continued innovation support to SME's.
4. Review the existing limitations of Irish marine test infrastructure and provide support to Universities / research providers to enable the provision of such infrastructure.

2.7 Conclusions and Next Steps

1. The initial sizing of the LRD and mooring optimisation analysis can now be undertaken independent of the Dublin Offshore team – this provides significant opportunity for the consideration of the technology in a wide geographical range of projects.
2. The knowledge transfer of the know how to perform the analysis is a good first step – consideration must now be focused on the product itself and undertaking the significant effort to ascertain operational track record and wider industry buy in from key decision makers such as project certification bodies, insurance providers, and financiers. The next steps for the LRD will be to finance, plan and execute the desired 10,000 hours relevant field operational testing.