Transition Site Opportunities for early FOWT Deployments

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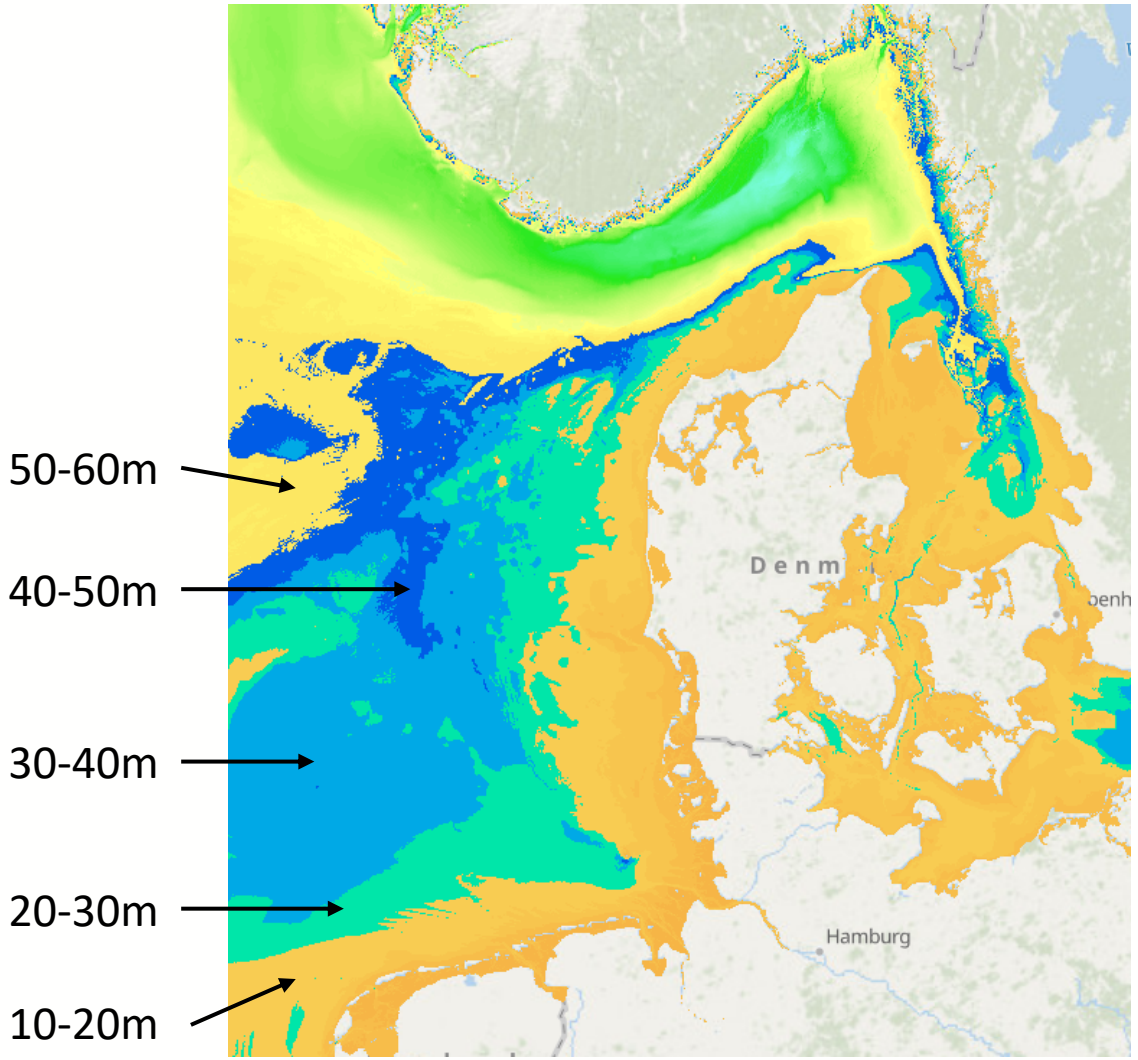
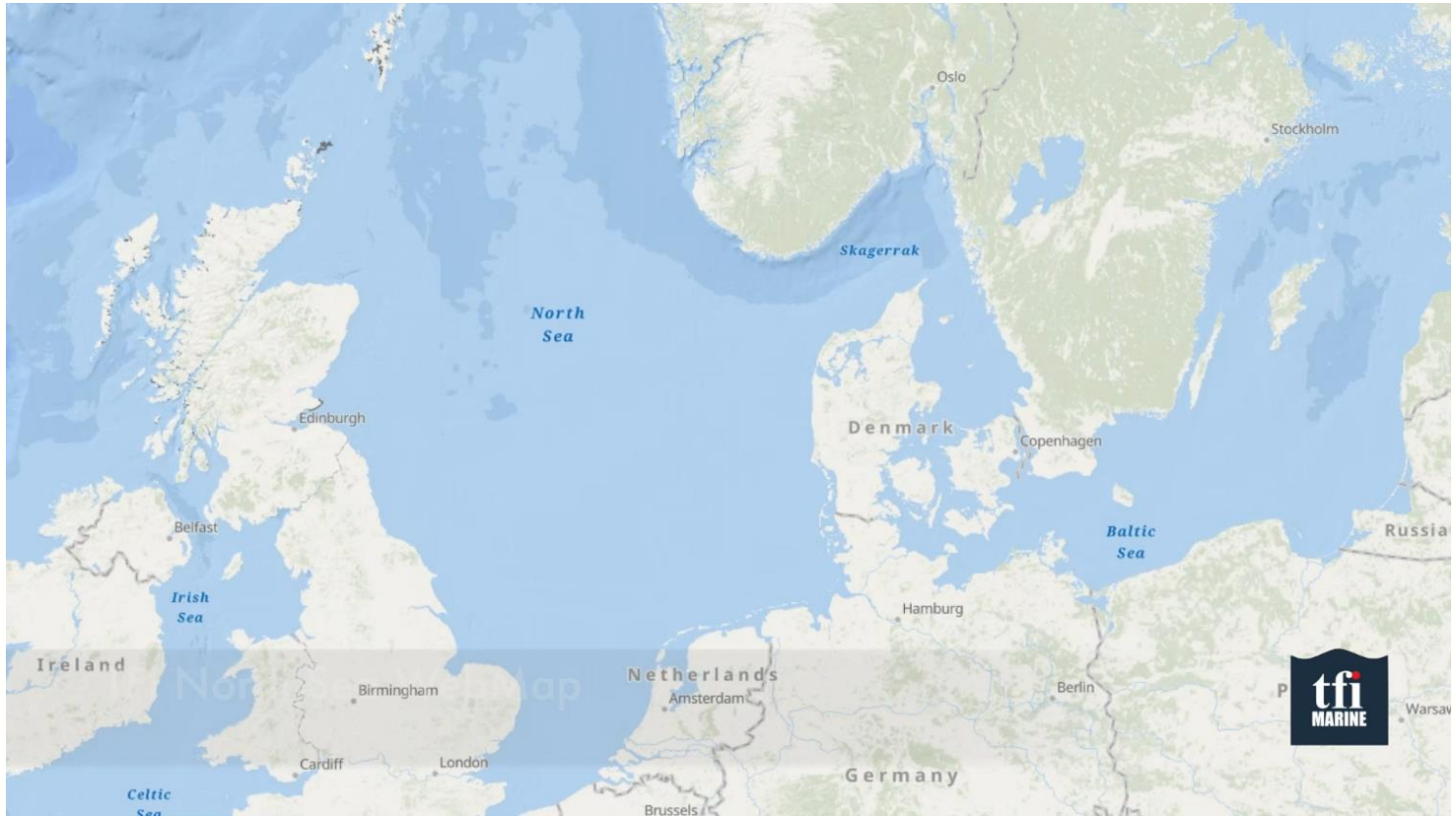
What are Transition Sites?

- Sites with water depths between typical fixed wind and floating wind depths
- Too deep for fixed wind
  - Possible with jackets to ~50m but adds to cost
- Too shallow for floating wind
  - Minimum FOWT depth depends on environmental conditions and platform
- Of high interest as often nearer to shore or close to existing offshore fixed wind sites and easier to access



How to locate Transition Sites of Interest?

- Water Depth
- Wind Speed?
- Wave height?
- Seabed type?
- Distance from existing infrastructure (wind farms, ports, grid, …)?
- Avoidance of shipping lanes, national parks, pipelines, …?
- Need to use tools which allow you to search by any and all of these criteria



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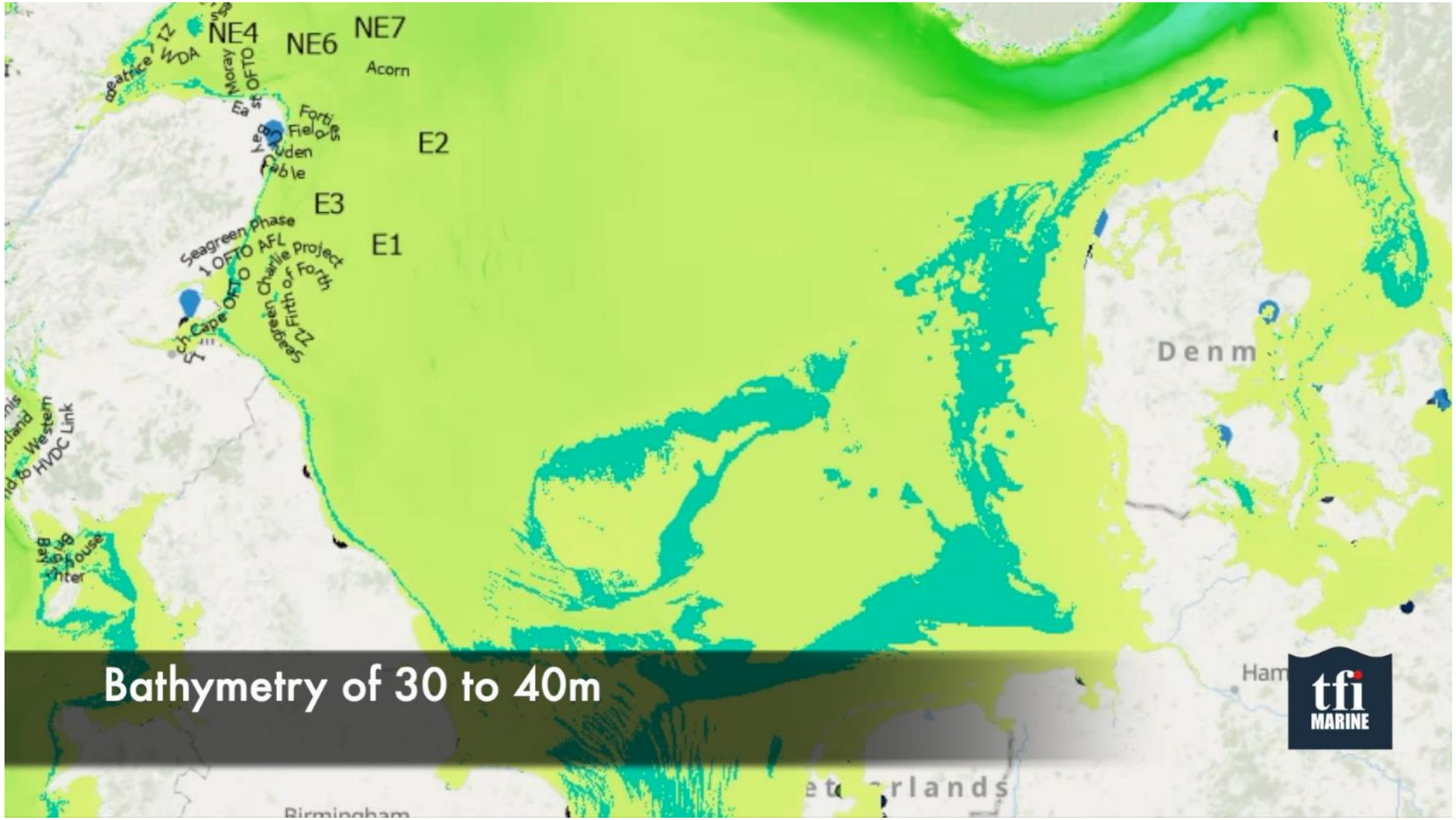

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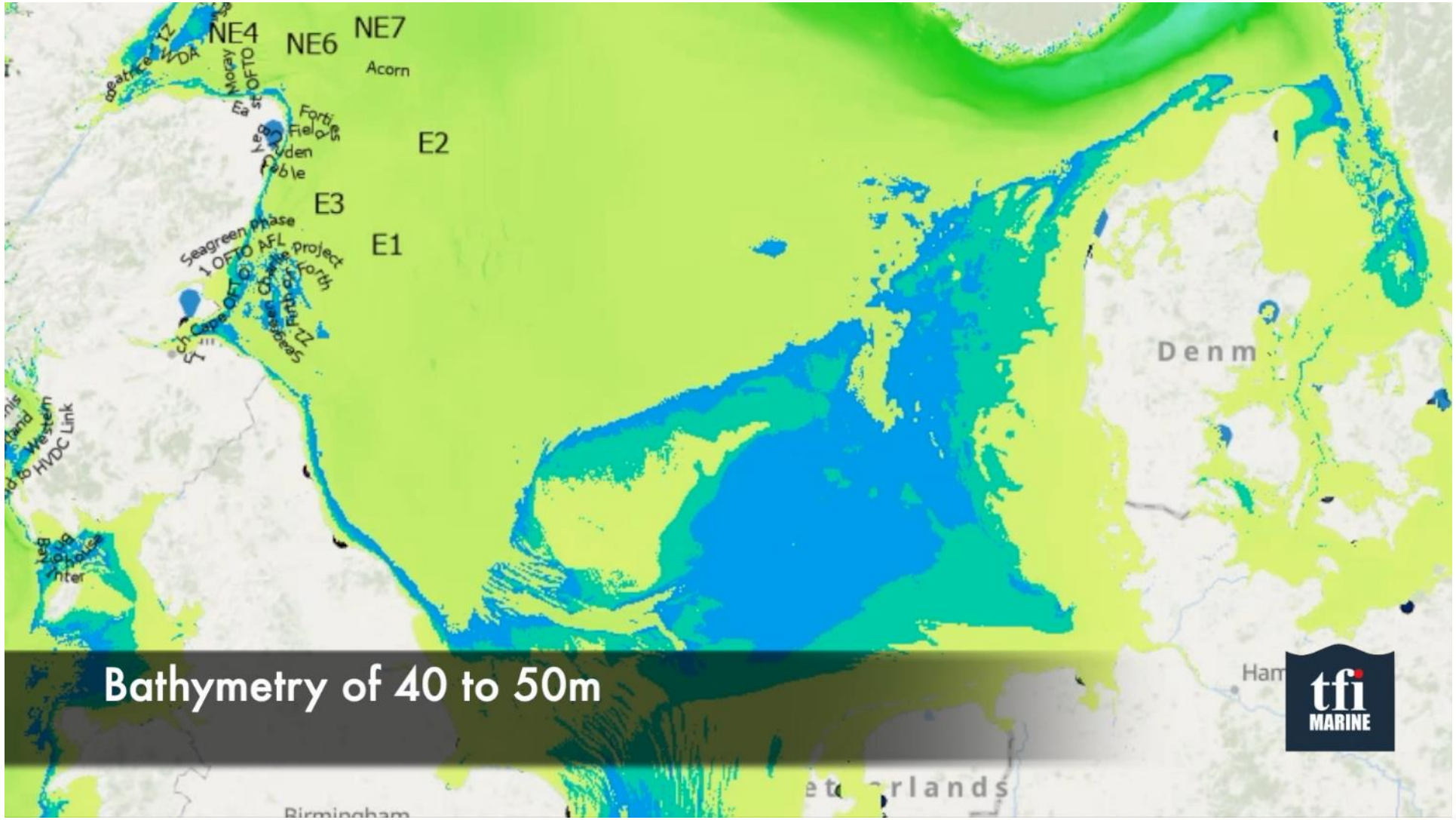

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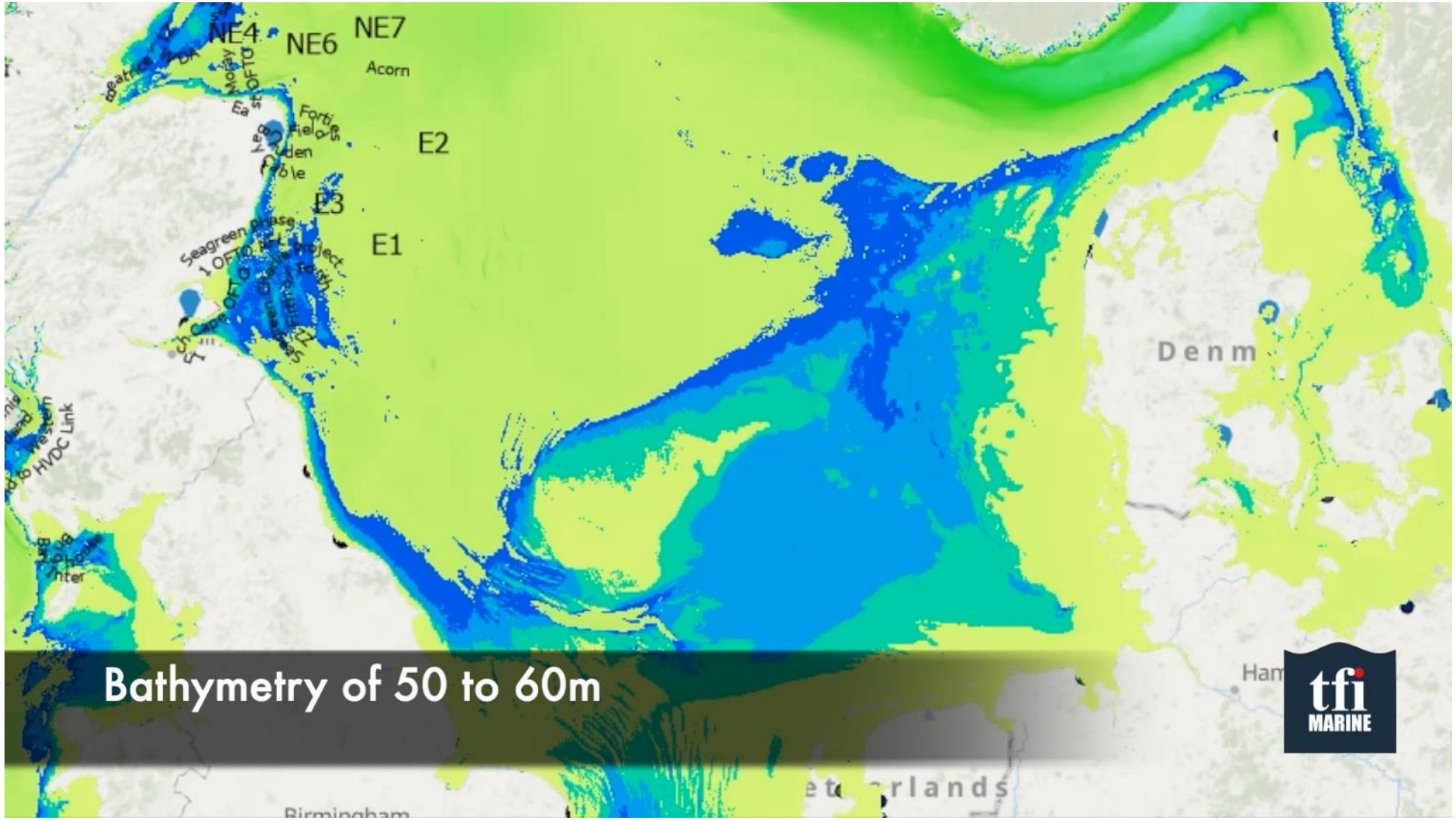

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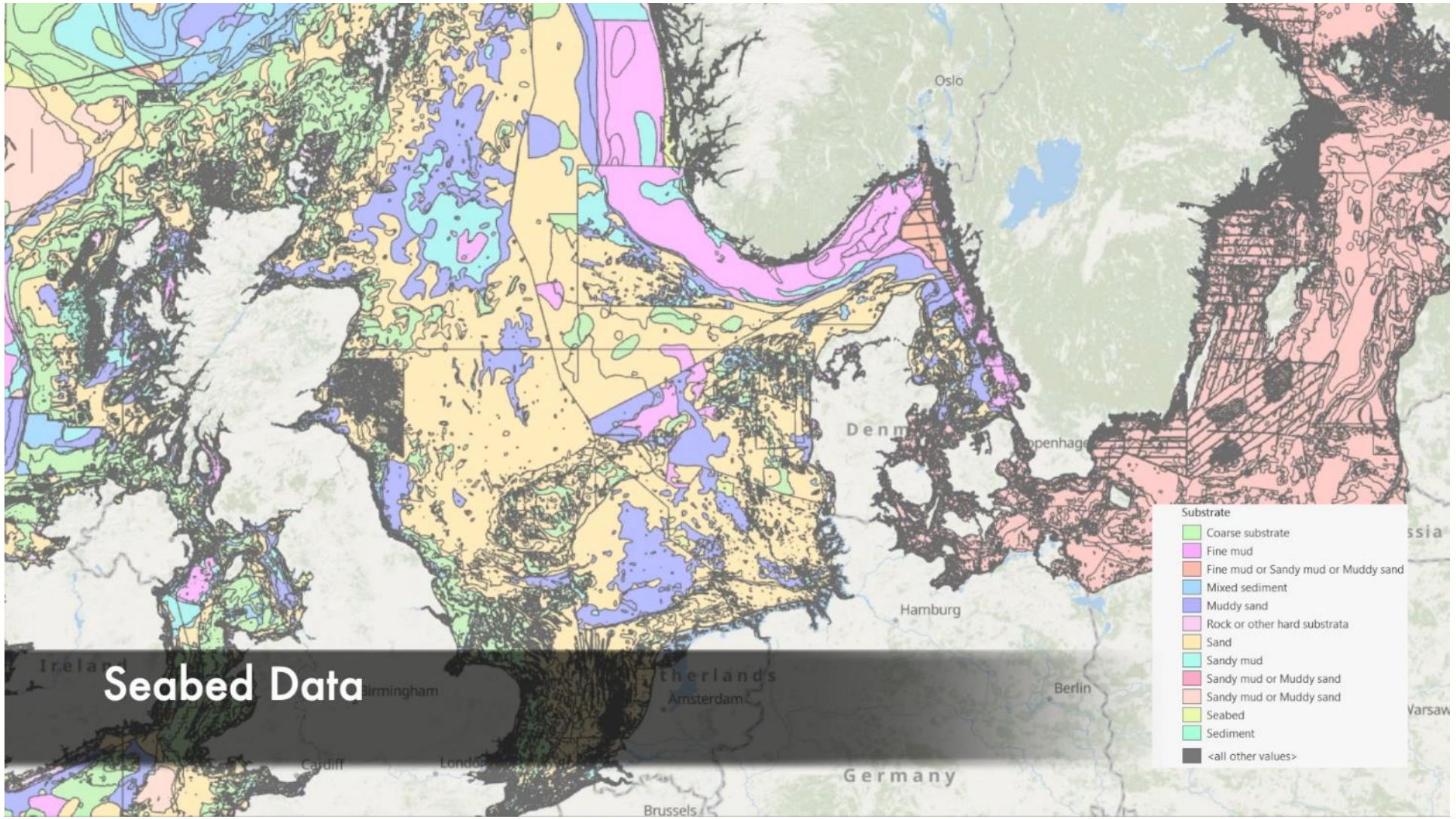

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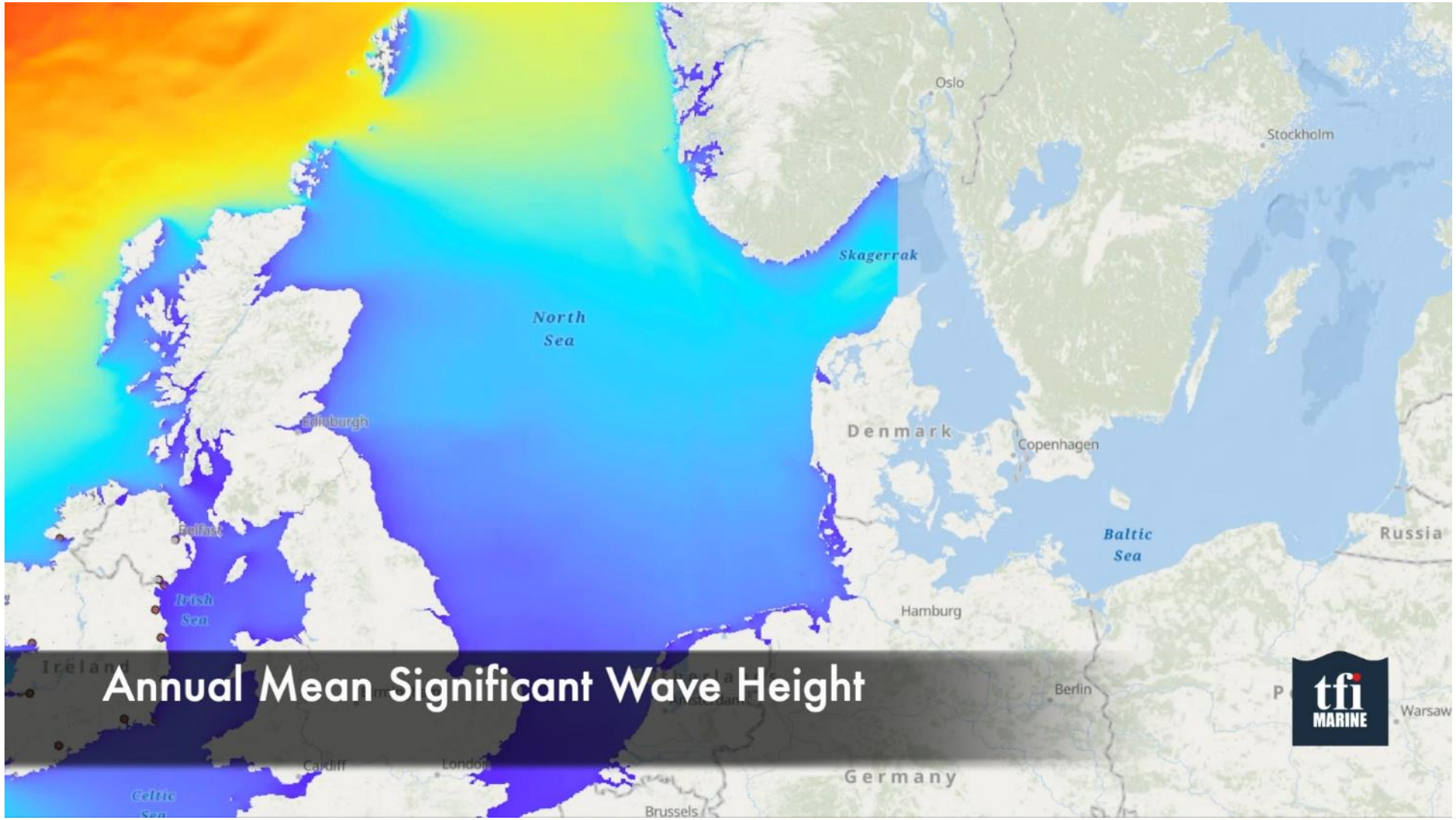

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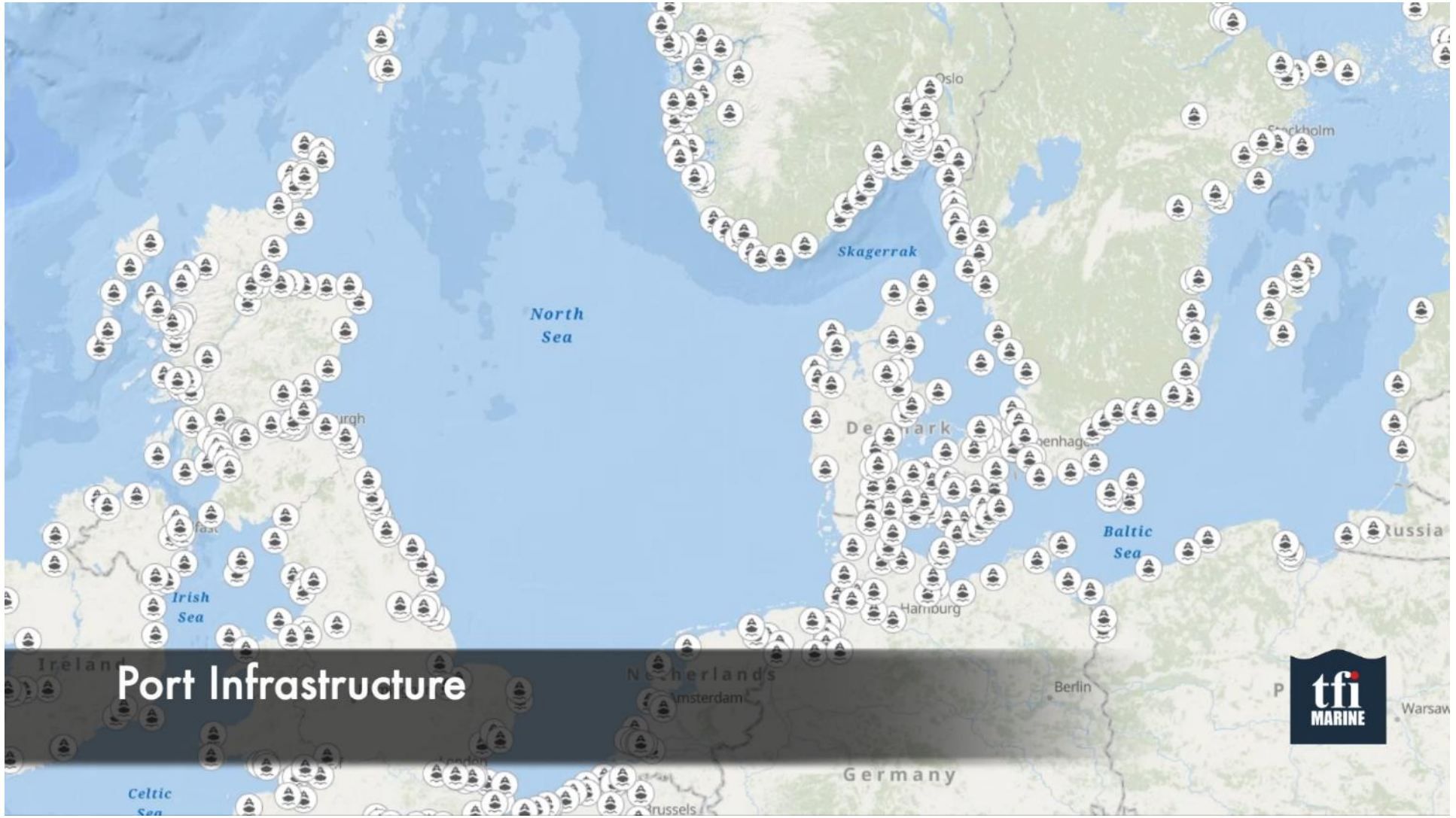

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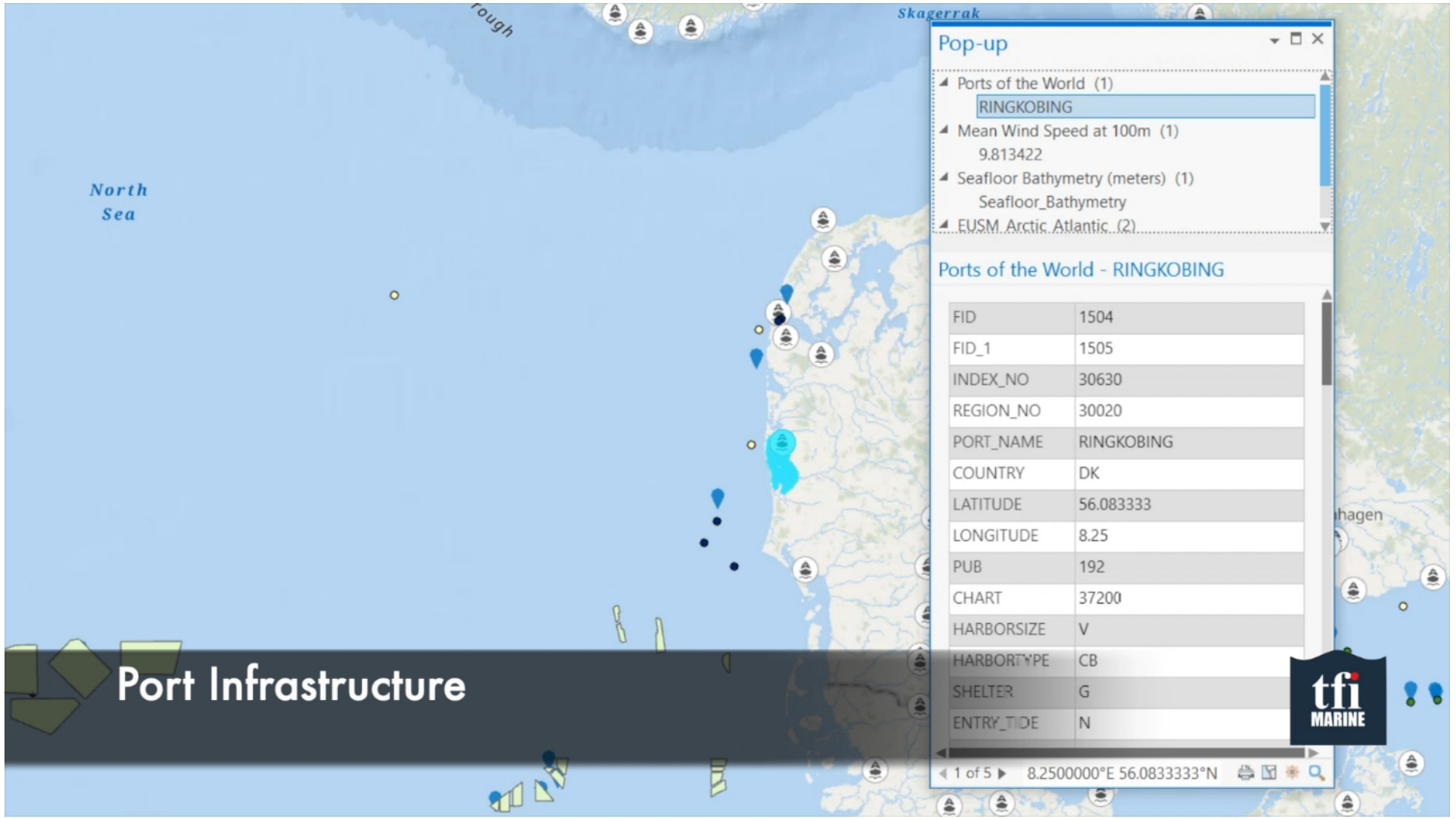

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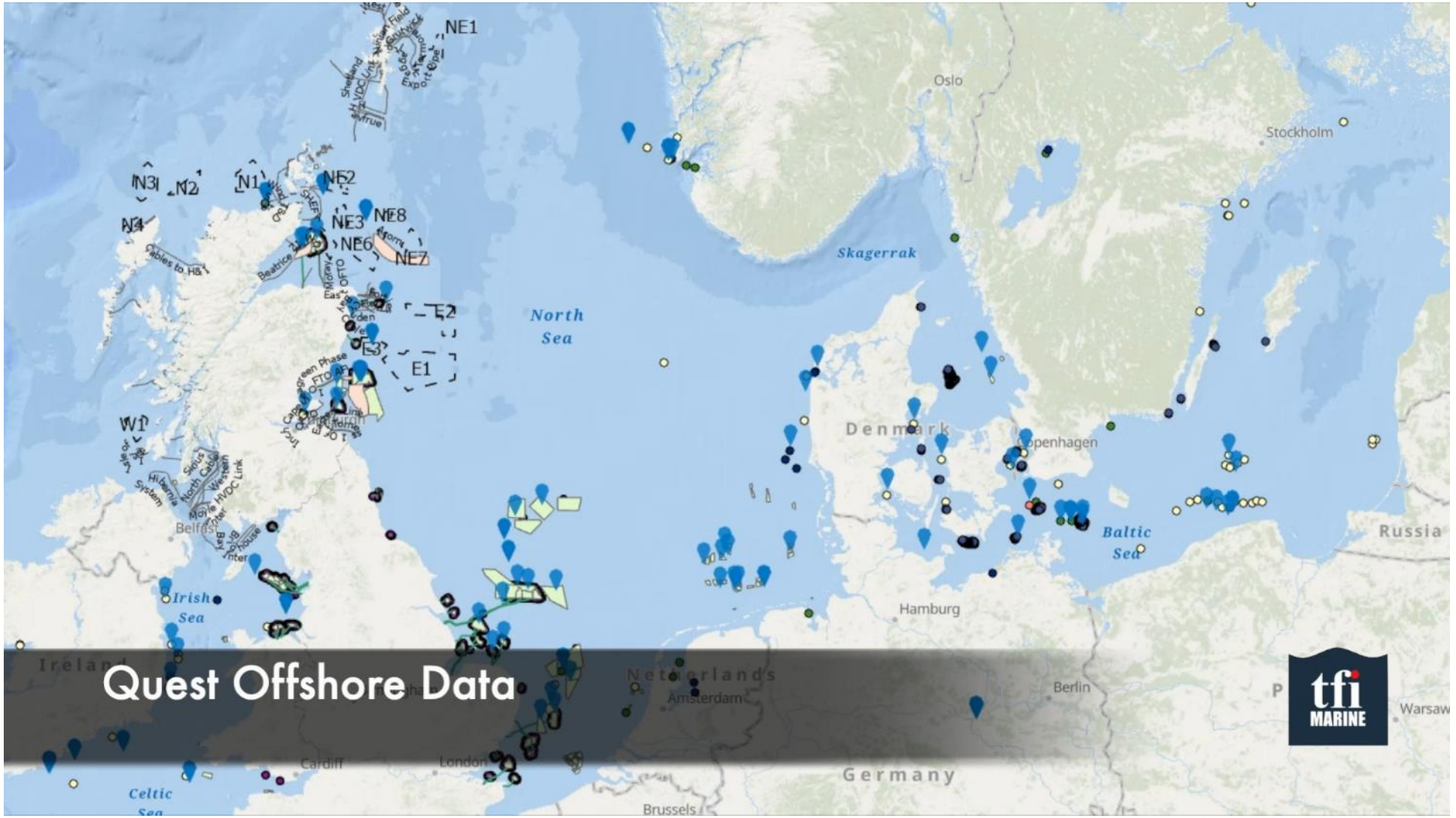

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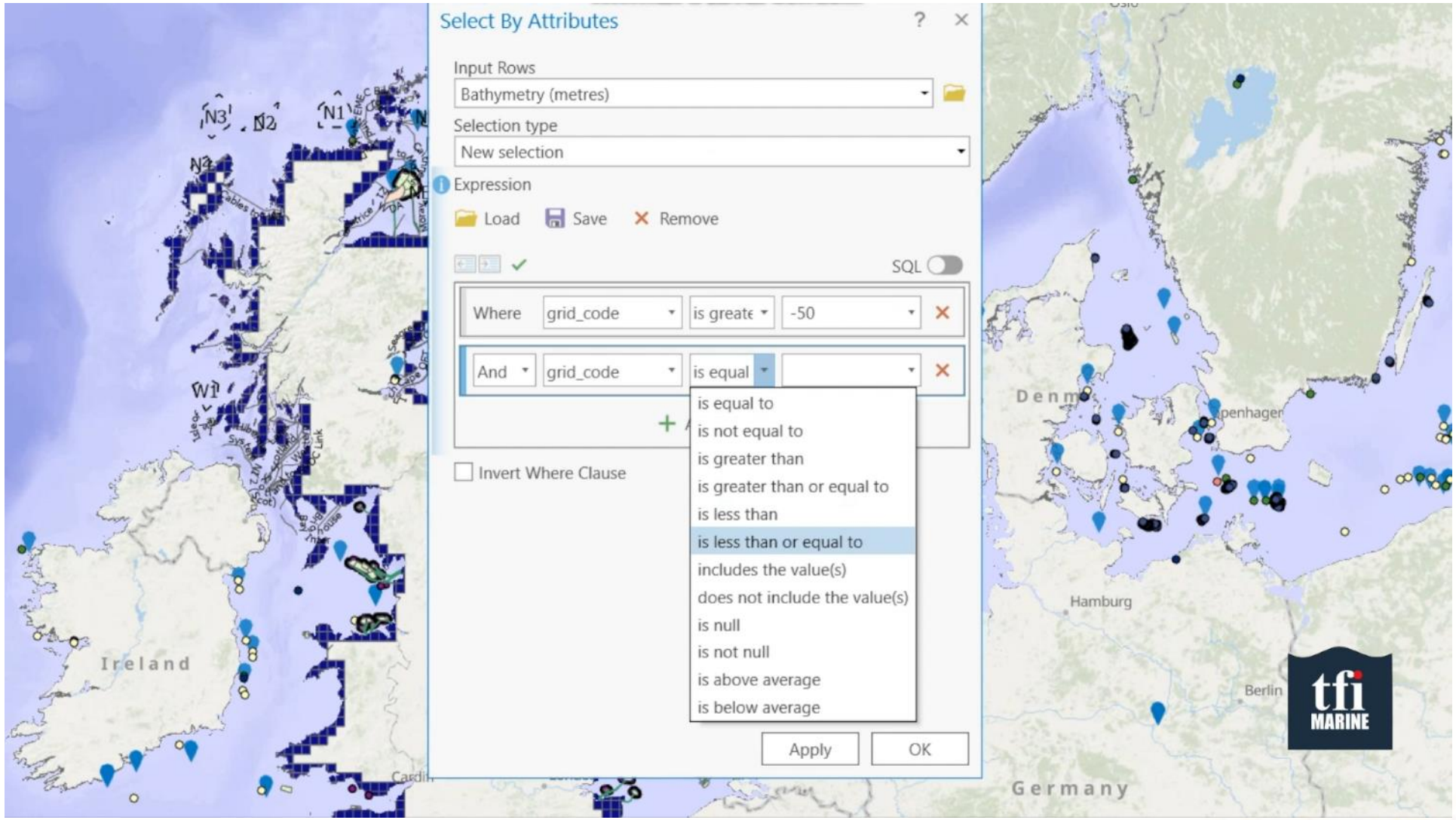

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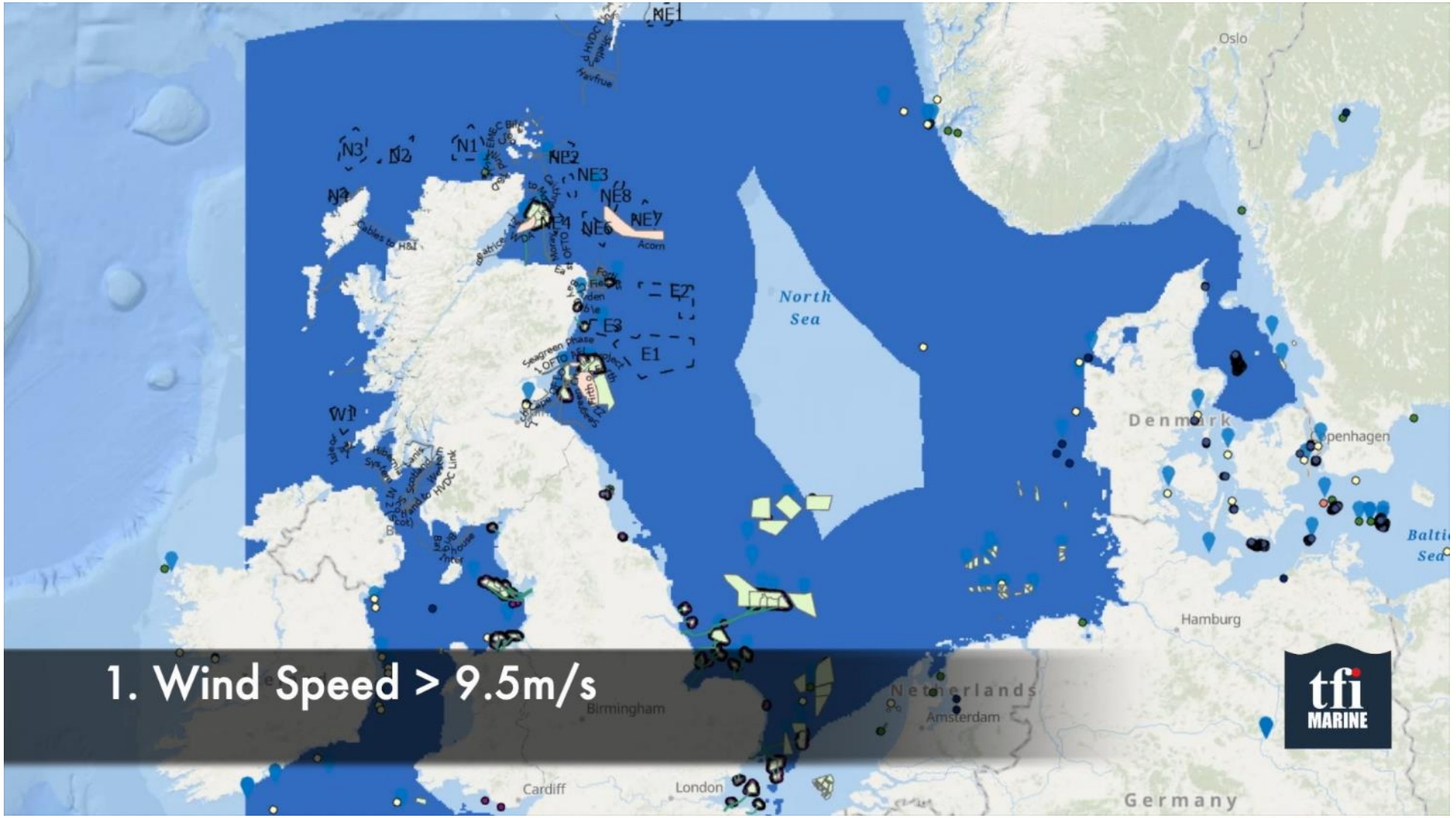

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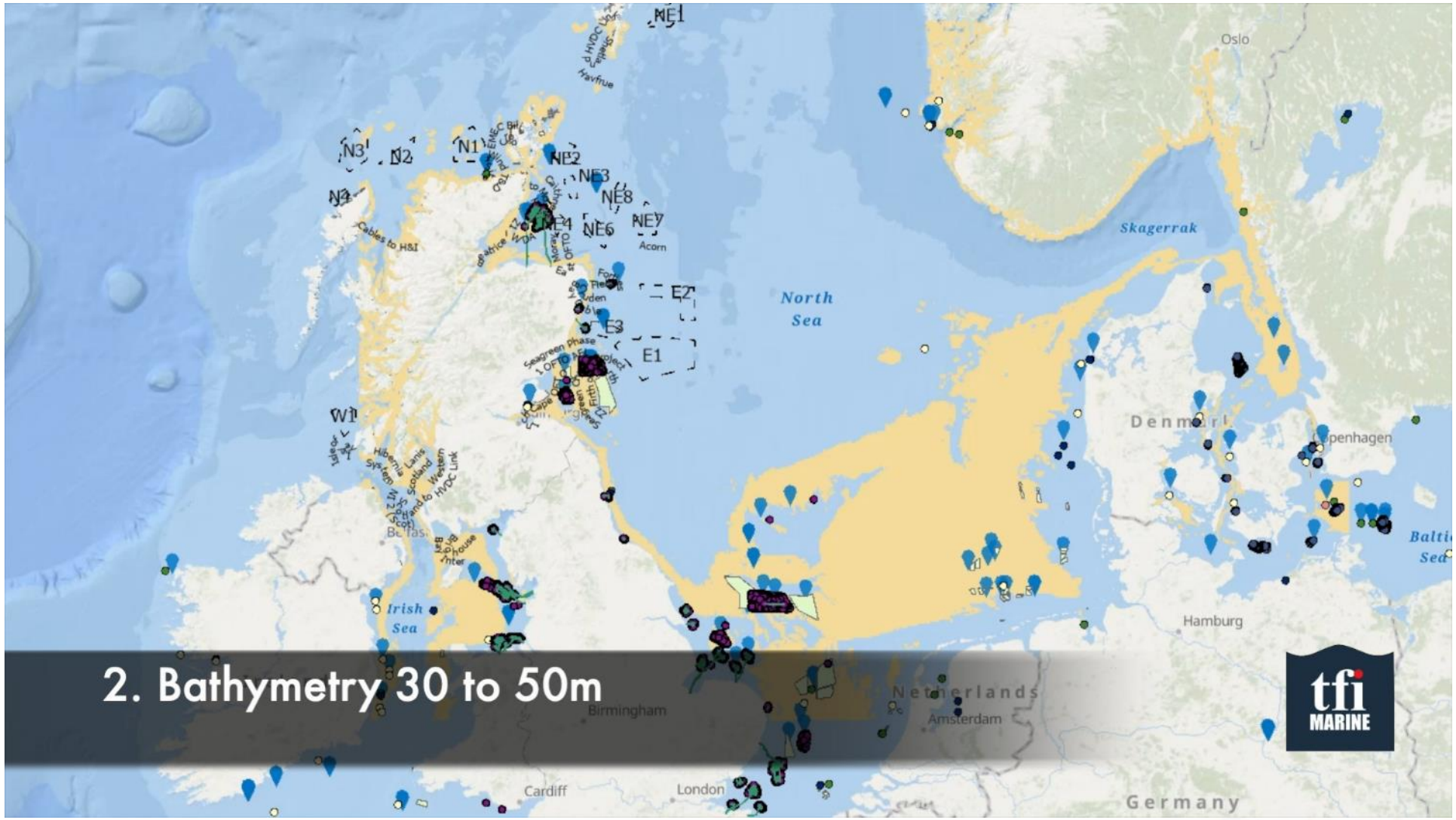

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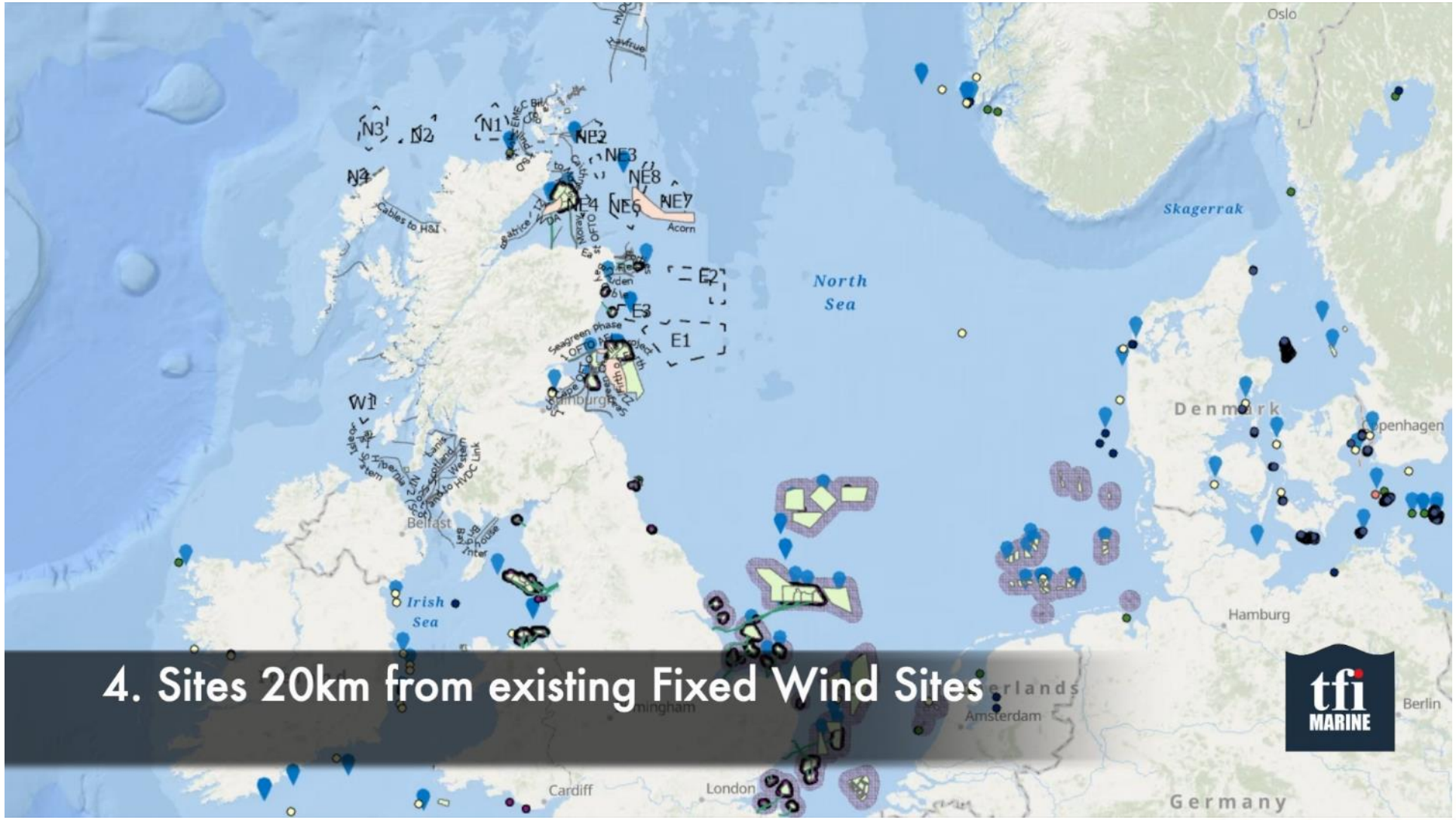

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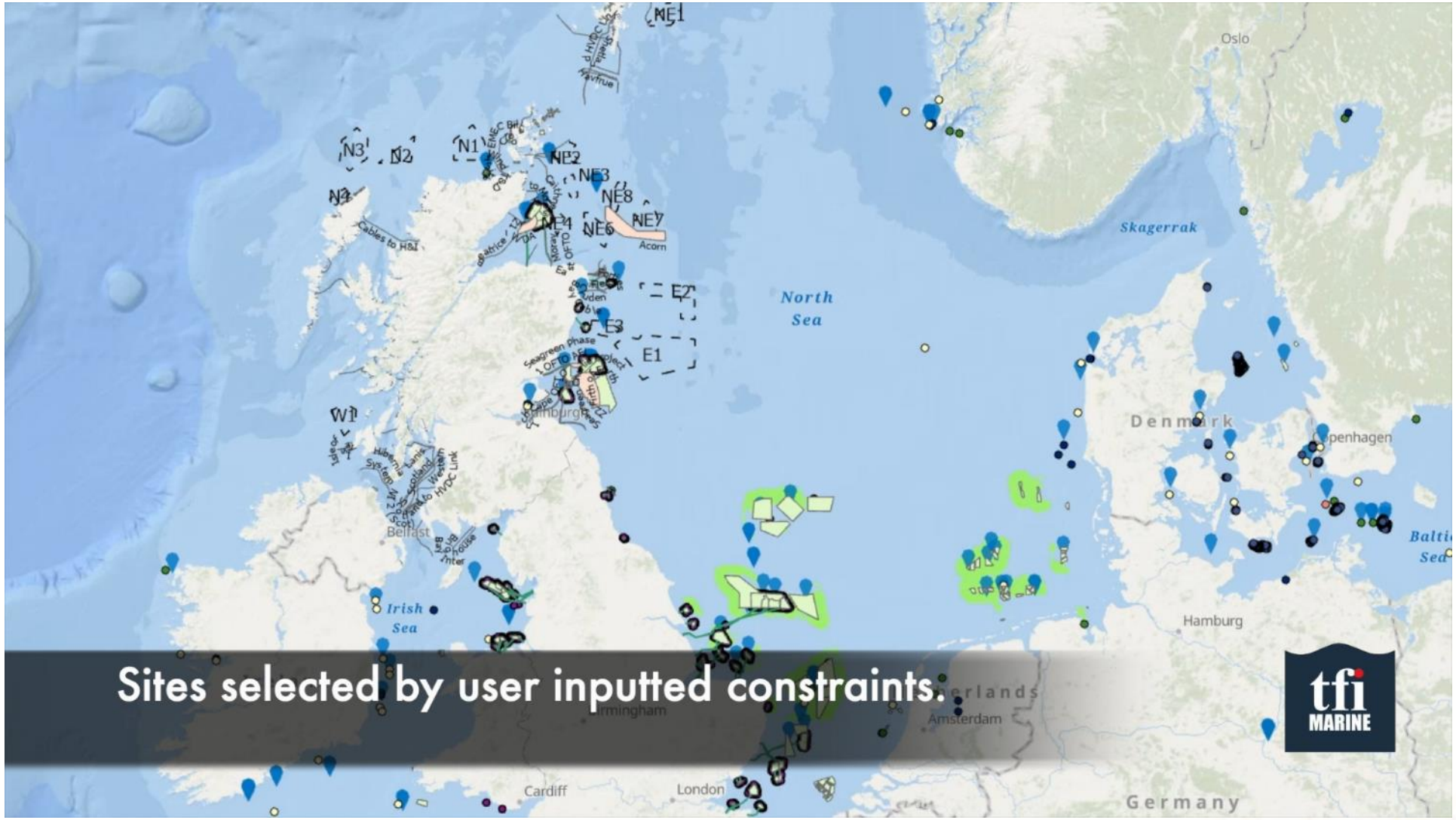

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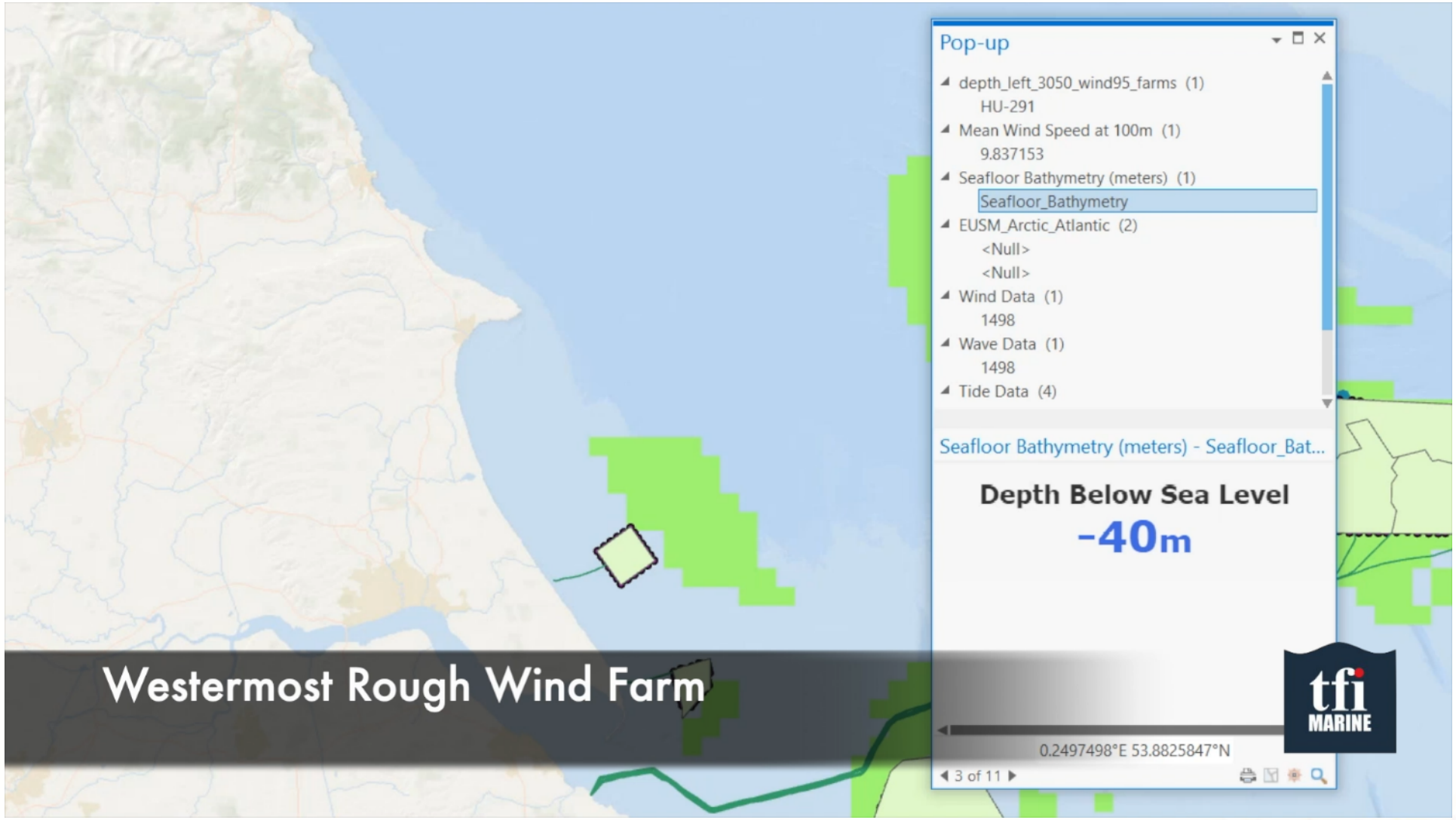
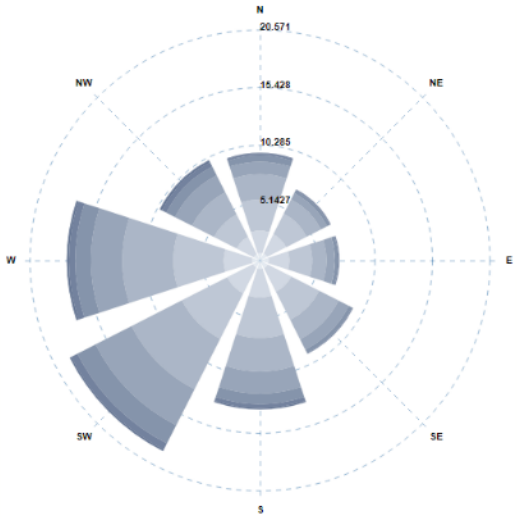


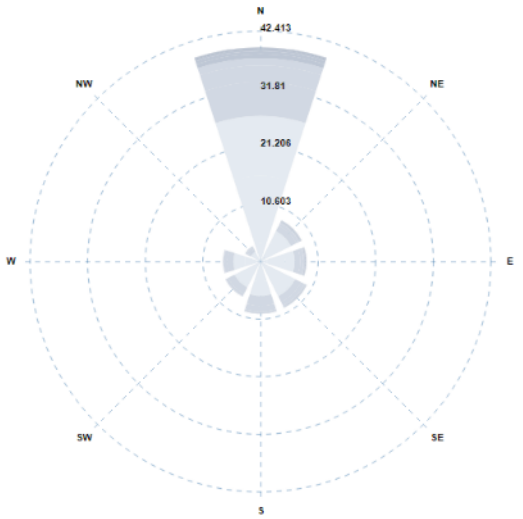
How to evaluate Transition Sites of Interest?

- Obtain environmental data for the site
  - Wind rose, wave rose, scatter diagrams, current, tides, …
- Choose a suitable platform type
  - For shallow water need a barge type platform
  - Build a suitable hydrodynamic and aerodynamic model
- Using mooring system design tools such as Orcaflex

Wind



Wave



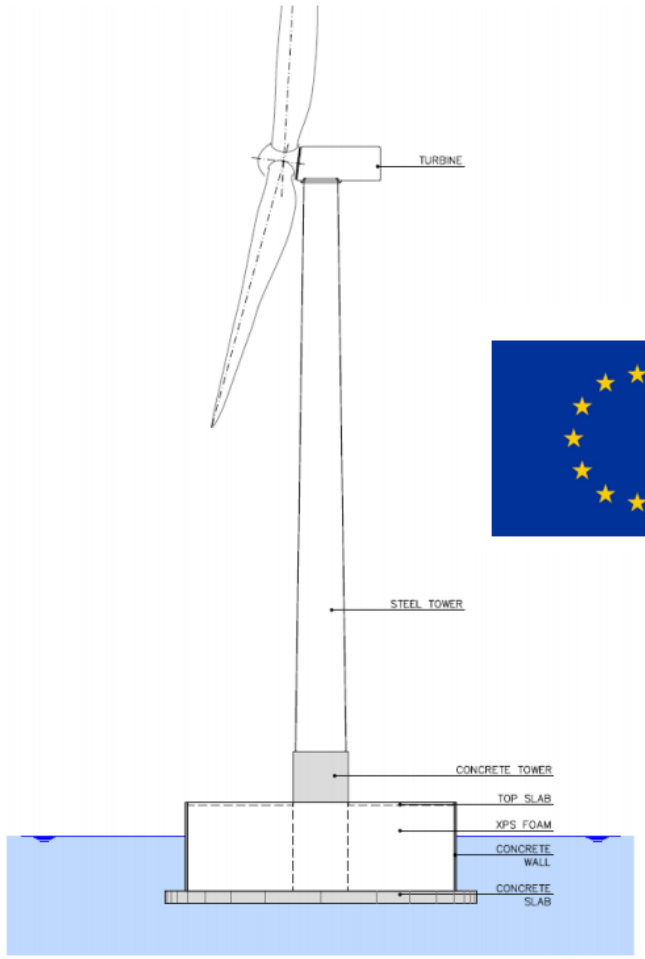
Wave

Floating Wind Solutions

How to evaluate Transition Sites of Interest?

- Obtain environmental data for the site
  - Wind rose, wave rose, scatter diagrams, current, tides
- Choose a suitable platform type
  - For shallow water need a barge type platform, e.g. FLOTANT
  - Build a suitable hydrodynamic and aerodynamic model
- Using mooring system design tools such as Orcaflex

FLOTANT Platform



FLOTANT -Innovative, low cost, low weight and safe floating wind technology optimized for deep water wind sites, has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No.815289

How to evaluate Transition Sites of Interest?

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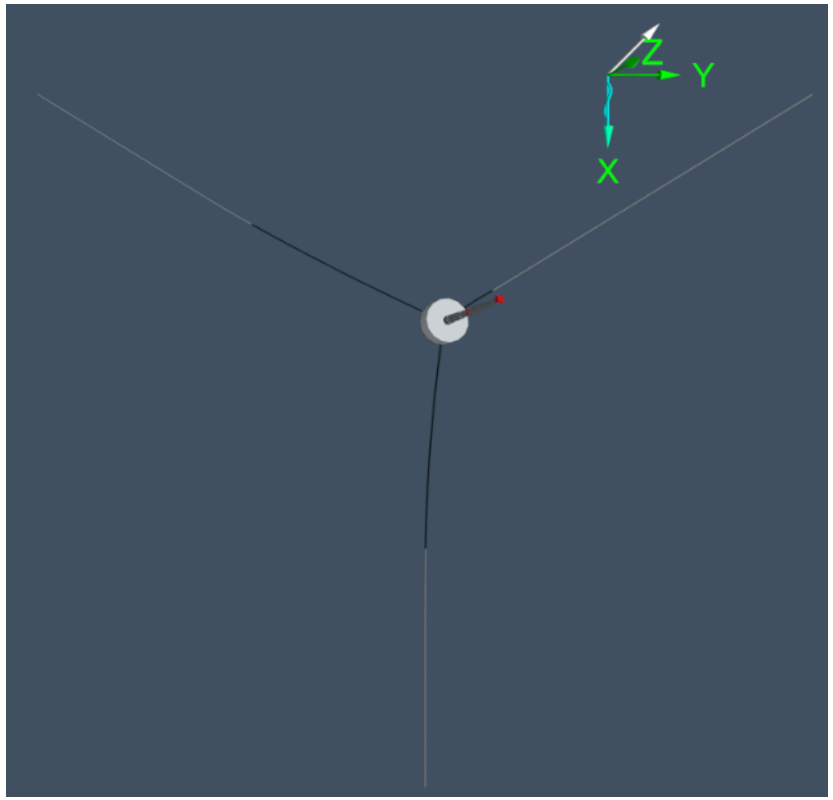
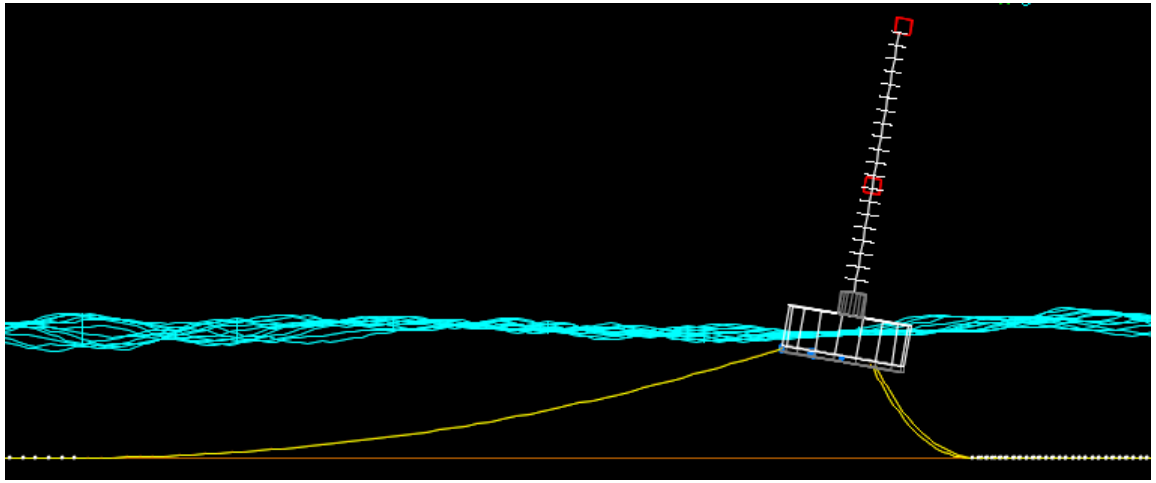
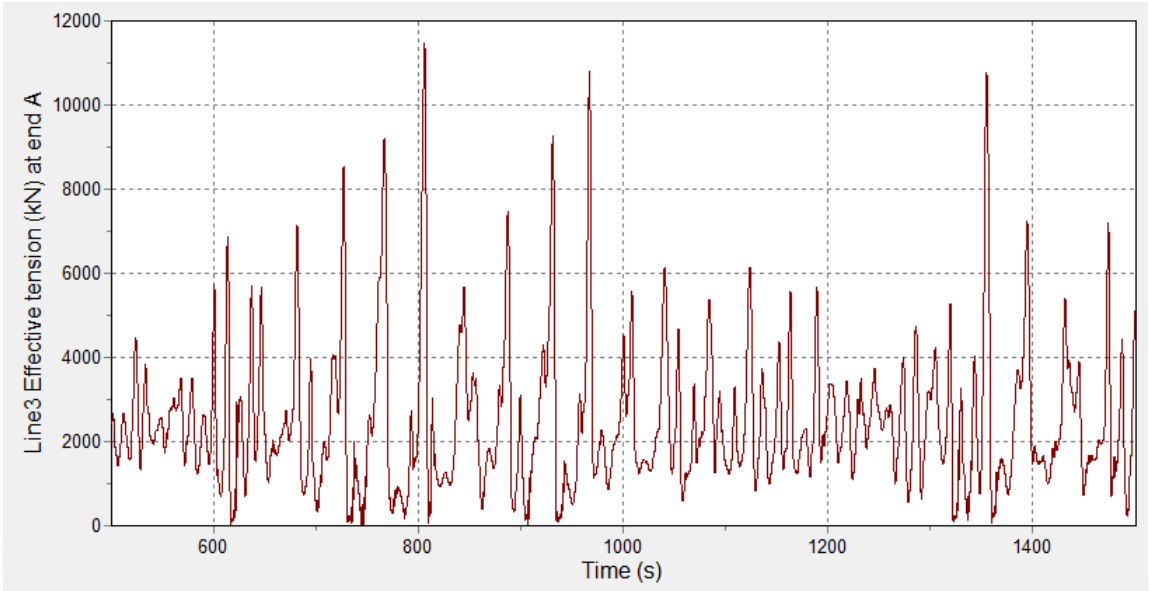
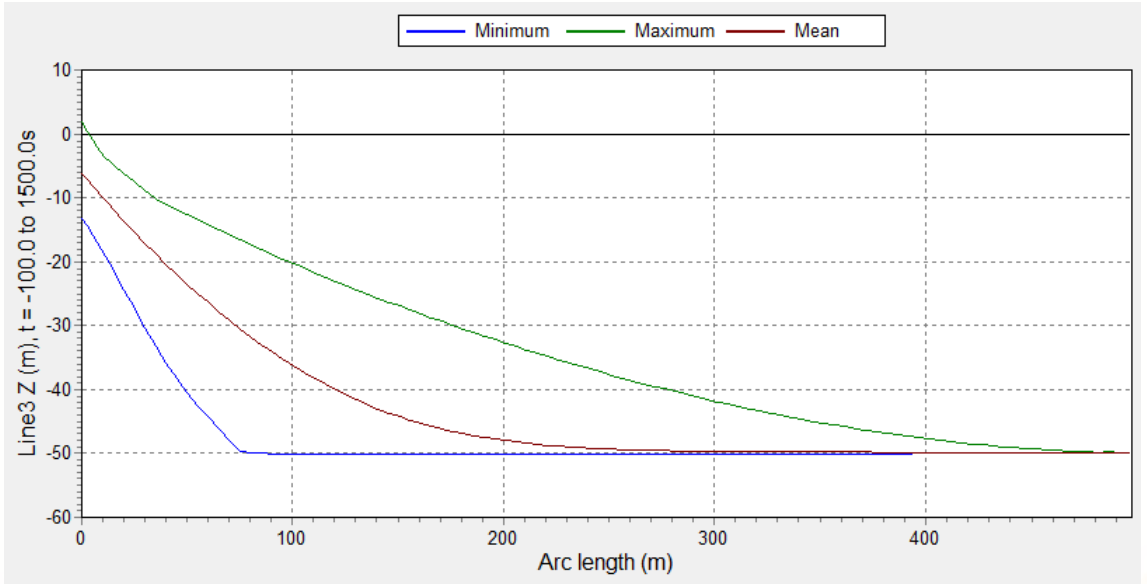


Traditional Mooring Solutions in Transition Sites

- Catenary Mooring Solution
  - Low water depth (50m)
  - High wave heights (6m)
  - Max wind thrust (~1900kN)
  - Long length of seabed interaction

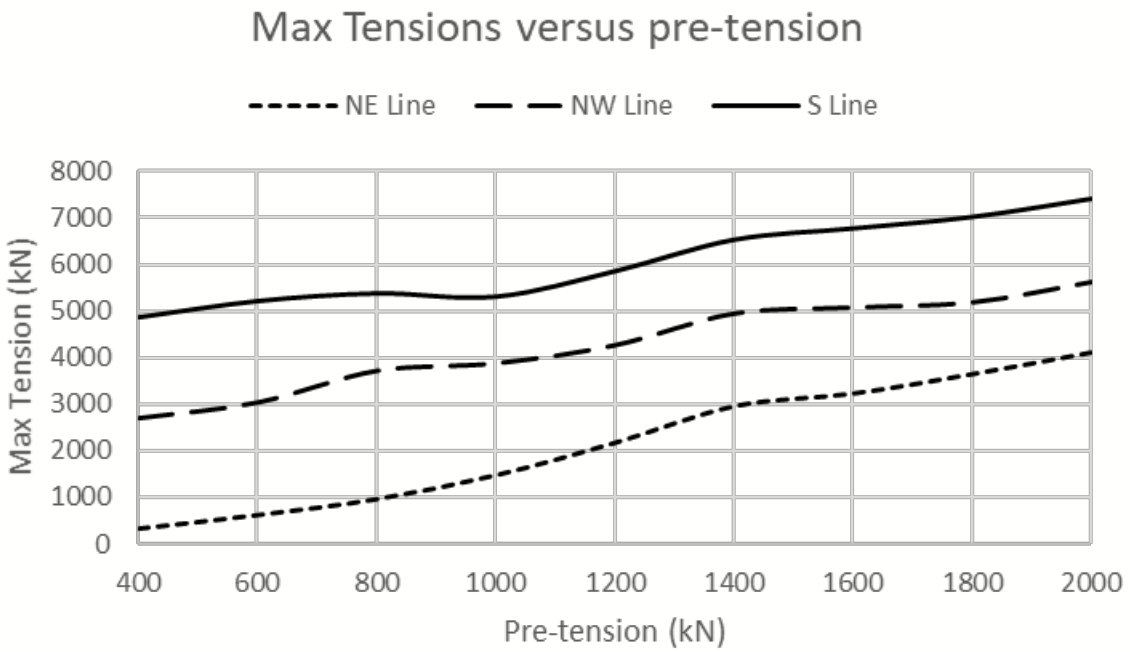


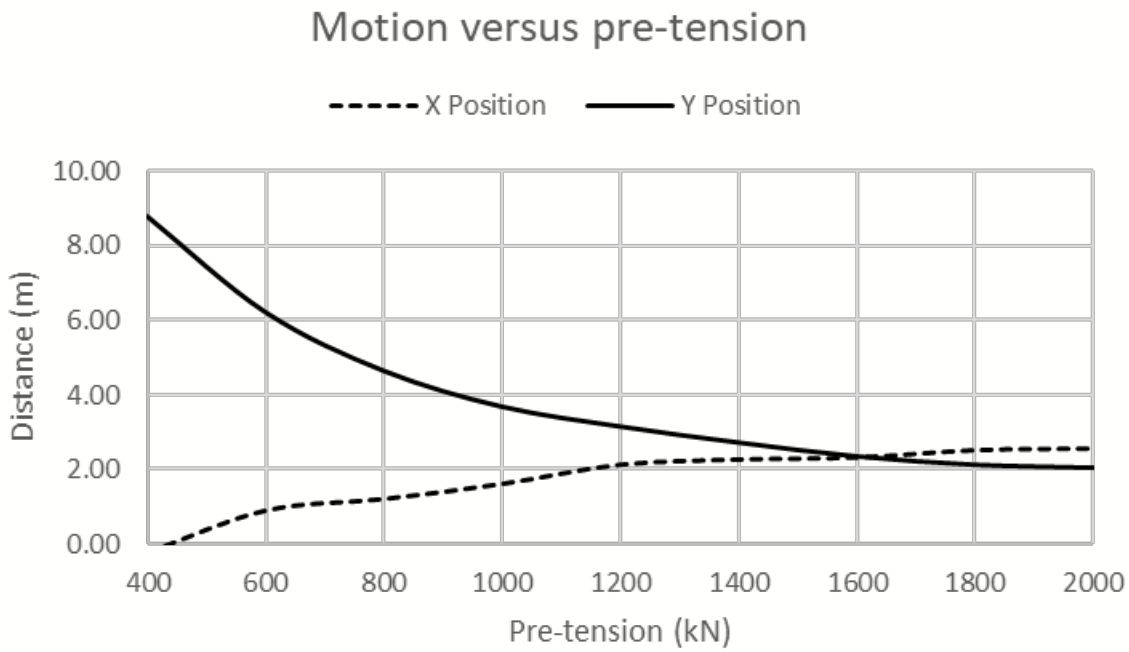




Traditional Mooring Solutions in Transition Sites

Adjust pre-tensions to eliminate snatch loads, and control motions

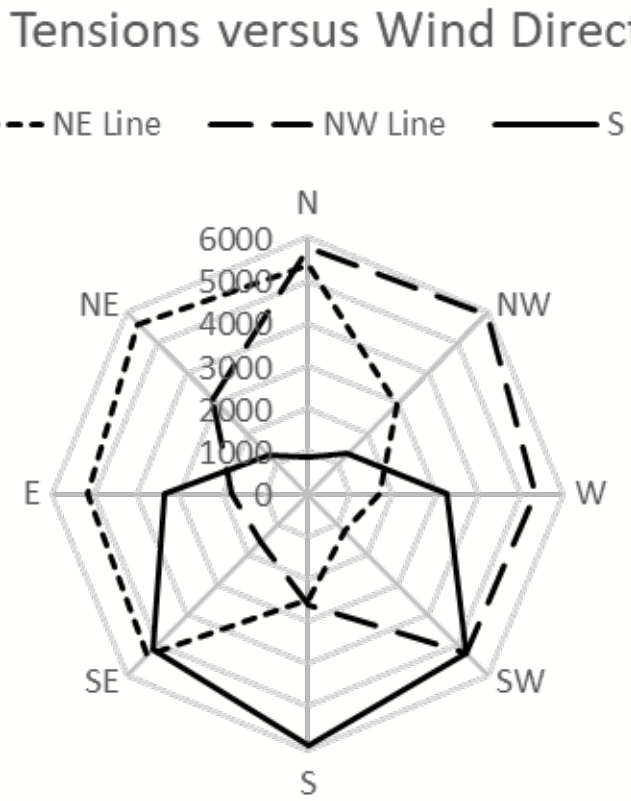




Traditional Mooring Solutions in Transition Sites

Check behaviour across all sea states and wind/wave directions

Waves from N in all cases

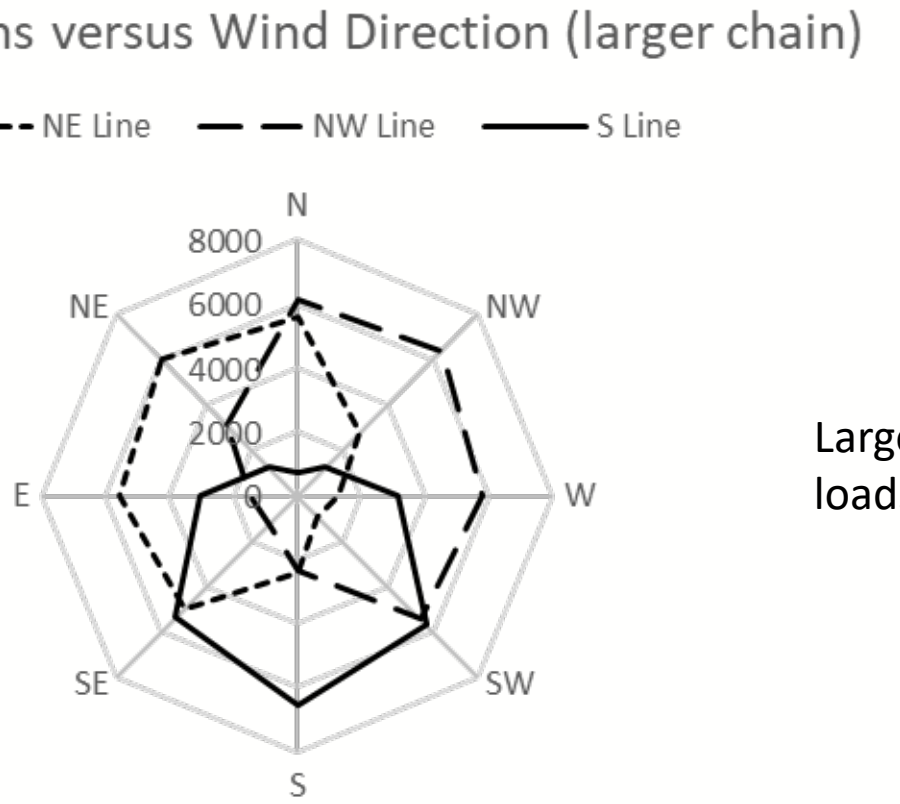


Tensions change across the mooring lines as wind direction changes. Some combinations give higher loads than base case (wind SW)

Traditional Mooring Solutions in Transition Sites

Adjust chain size for maximum loads and lifetime corrosion

Waves from N in all cases



Larger chain weights result in higher loads

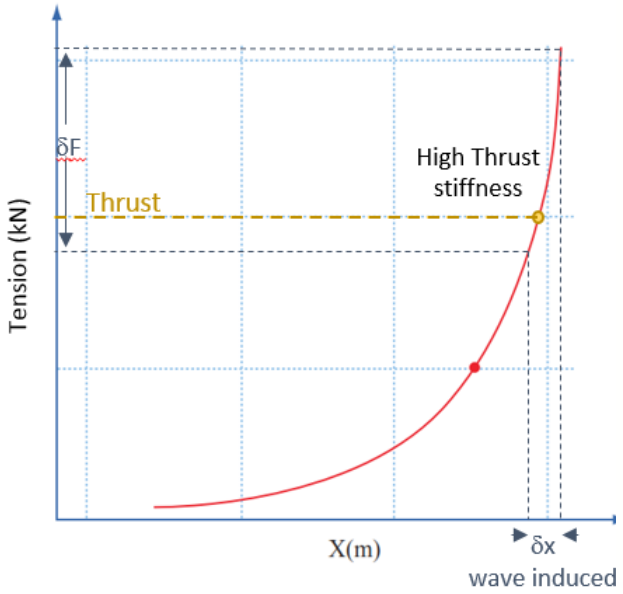
Traditional Mooring Solutions in Transition Sites

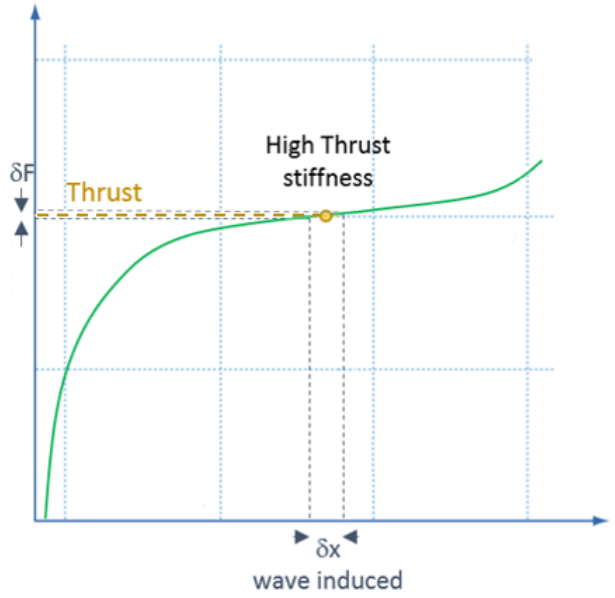
- Repeat and re-iterate to identify viable mooring solutions
  - Keep surge and sway within acceptable ranges for dynamic cable
  - Keep pitch and roll within acceptable range for platform/turbine
  - Choose suitable mooring component dimensions for expected loads and lifetimes
  - Ensure all the above criteria are maintained across all possible operating conditions

- Find the viable option with lowest cost (capex & installation)
  - Look at other mooring alignments
  - May need to increase the # of mooring lines to reduce maximum tensions
  - Repeat for alternative traditional mooring system solutions (Fibre rope options, Semi-taut mooring options, Clump weight options)

Novel Mooring Components to add Compliance

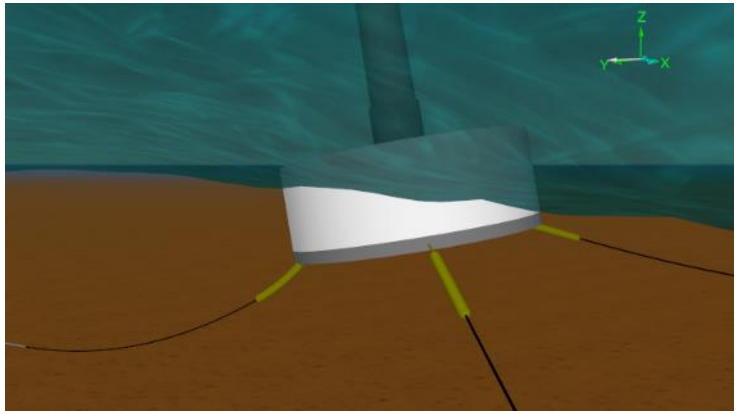
- Polymer Mooring Spring
- Shape of spring defines response
- Size and response tailored to project needs
  - Stiff response a lower tensions but compliant at higher tensions

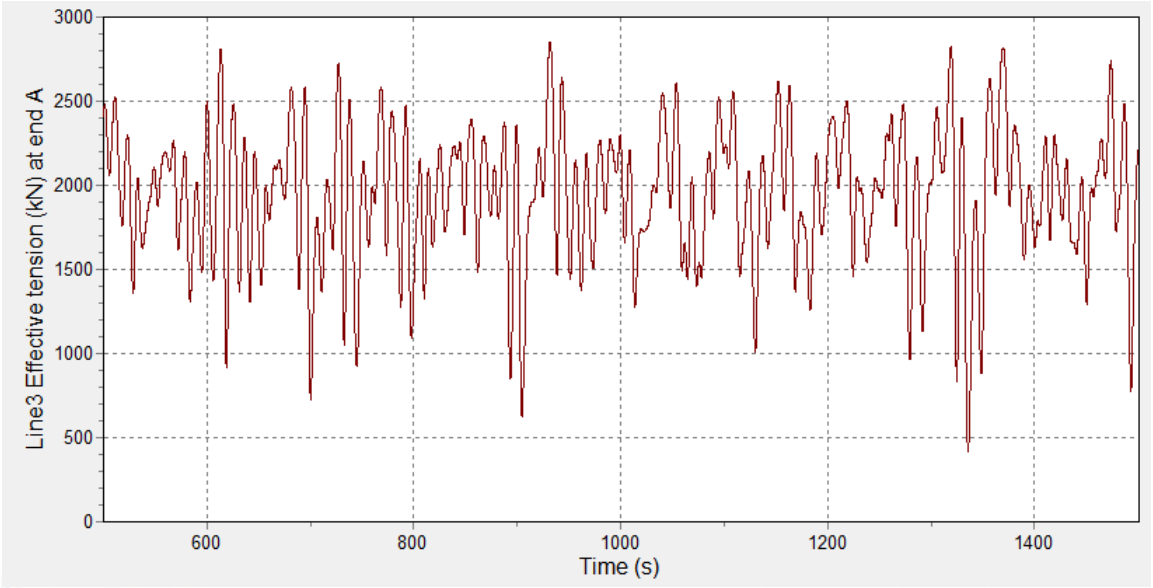


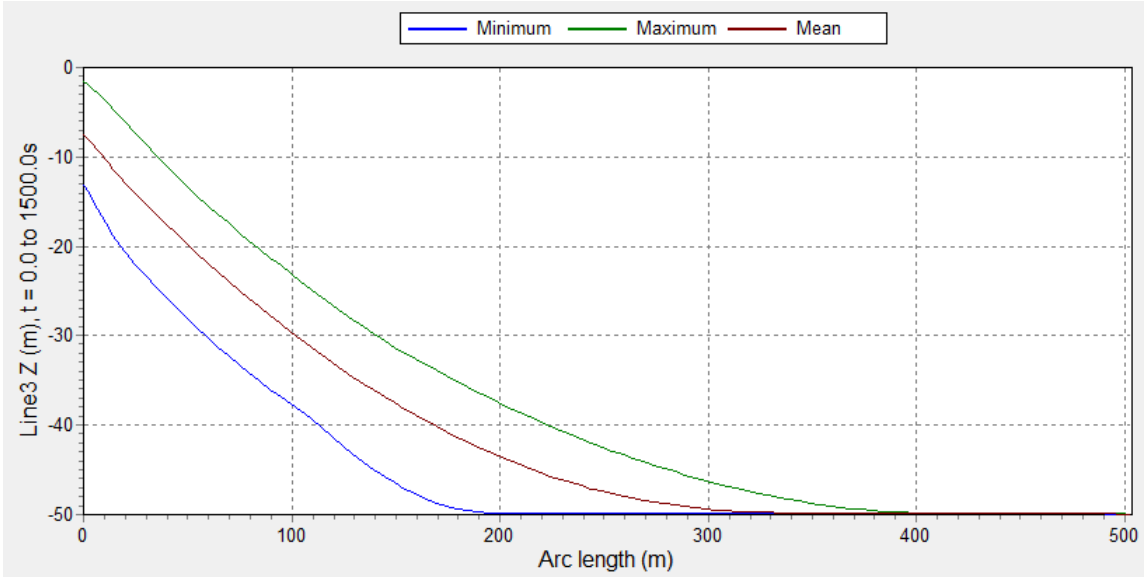


Catenary with Spring in Transition Sites

- Catenary Mooring Solution with springs
  - Substantially lower loads than traditional catenary solution

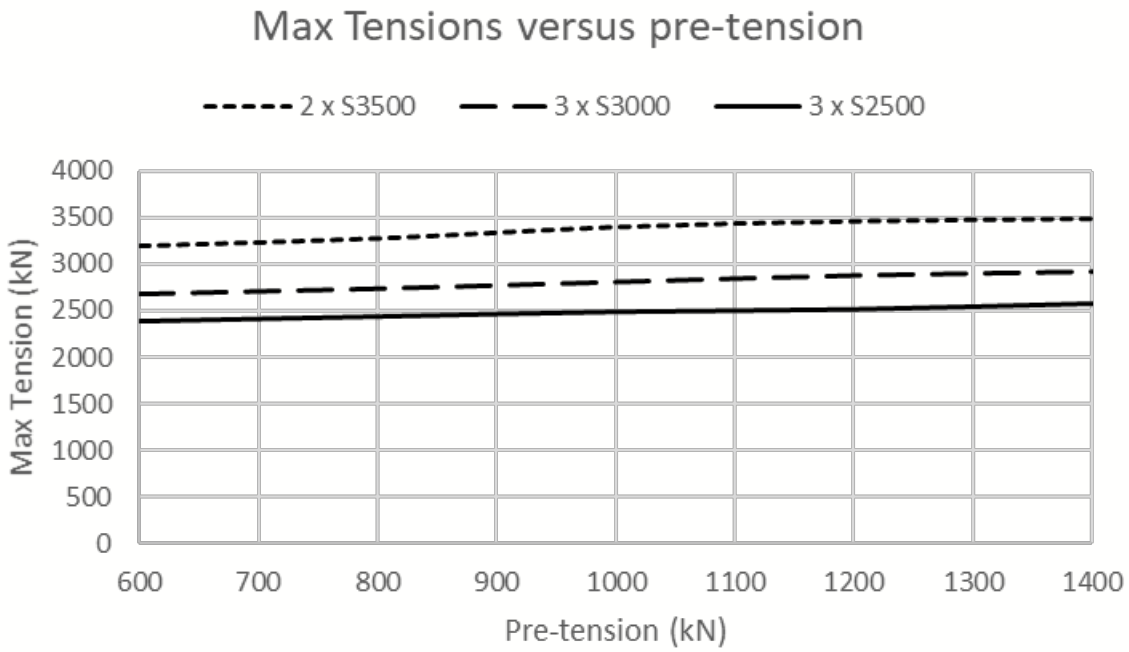


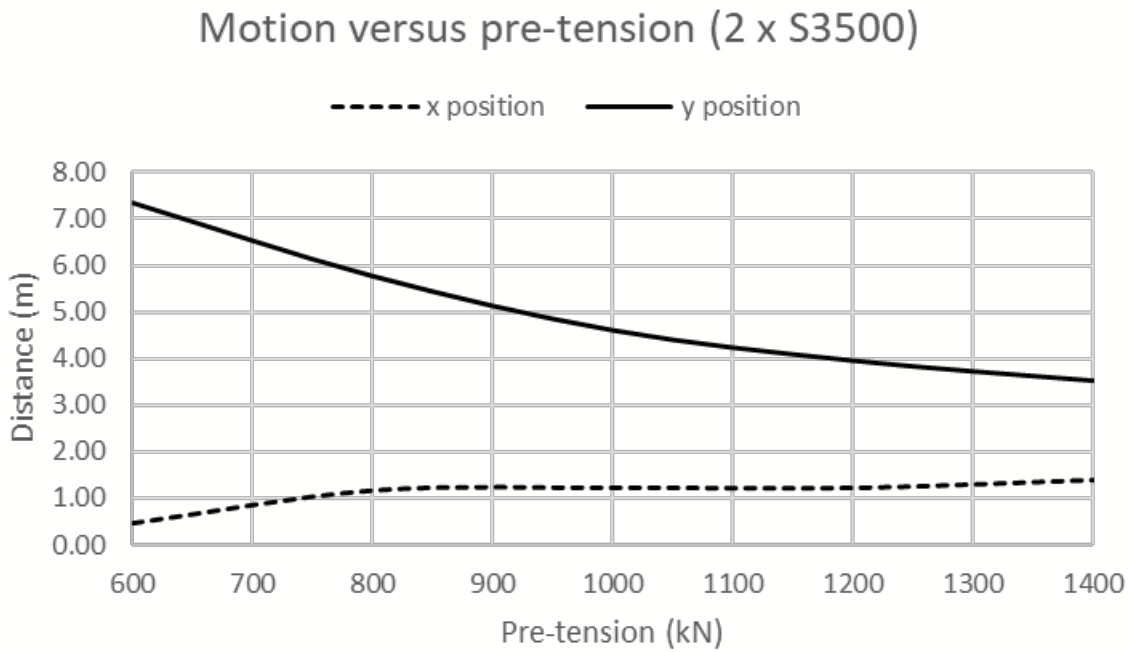




Catenary with Spring in Transition Sites

Choosing the right spring size / number





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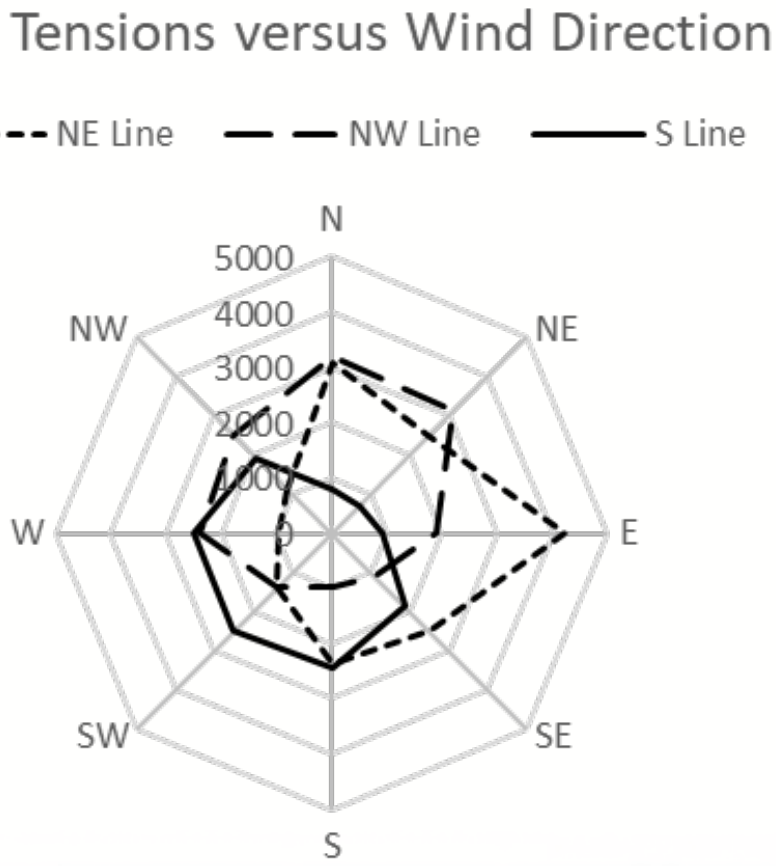
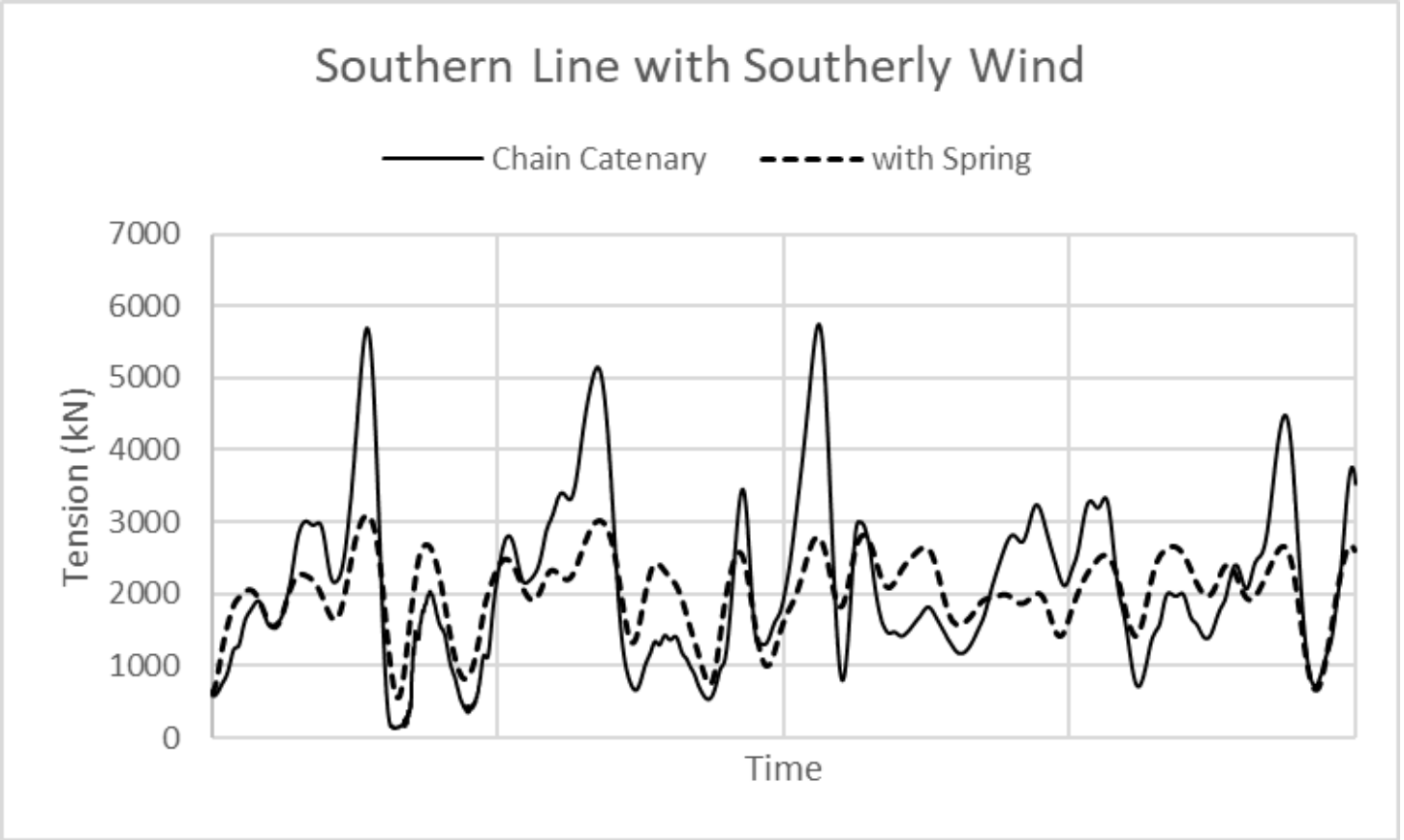


Tensions change across the mooring lines as wind direction changes.

Comparison

Use of springs substantially reduces the maximum tensions in the mooring lines



Comparison

Springs reduce design loads by 30-60% in the selected shallow water site

	Max Tension (kN)		Reduction	
	chain	spring	kN	%
NE Line	6031	4214	1817	30%
NW Line	6413	3179	3234	50%
S Line	6573	2503	4070	62%

Comparison

Reduced design loads has a substantial impact on CAPEX

	Chain				Spring		
	Ø (mm)	Length (m)	Weight (T/m)	Weight (T)	type	#	Cost (M€)
Catenary	127	1543	0.353	545	-	0	**1.36**
with spring	90	1418	0.177	251	S3500	6	**0.98**

~€400k saved before the lower anchor and installation costs are considered

Fatigue reductions (of ~30%) will deliver even more cost savings or lifetime extension

Conclusions

- Large areas of transition sites in many locations worldwide
  - Currently unsuitable for use due to costs and mooring challenges
- Novel mooring components, coupled with suitable FOWT platforms, drive down the cost of using these sites
- These offer appealing opportunities for early FOWT deployments
  - e.g. Expansion of existing wind farms with FOWT
  - e.g. Replacement of current planned fixed bottom wind farms with FOWT