Intro Sideshore Technology

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Purpose of Sideshore Technology

We believe that modern data science and optimisation methods will play a key role in the transition to a more sustainable world

Our purpose is to accelerate the energy transition by designing smarter wind farm layouts

Our main service is to optimise the positions of offshore wind turbines, substations and cables *with algorithms as opposed to engineering judgement*

Part 1: Wind farm layout optimisation

[Check out our introduction video]

Why perform wind farm layout optimisation?

- Wind farm layout significantly influences cost across various project domains
  - Yield: 1% reduction of wake effects => ~€30 to 40 million EUR during the lifetime of the wind farm
  - CAPEX: wind farm layout has a major impact on foundation cost: ~€5 to 25 million EUR
    - Avoiding deeper areas & reducing number of water depth clusters
    - Locally avoiding sand waves and difficult geotechnical conditions
    - Reducing the needs for seabed preparation or scour protection

- To date, wind farm layouts are based on engineering judgement or yield analyses only

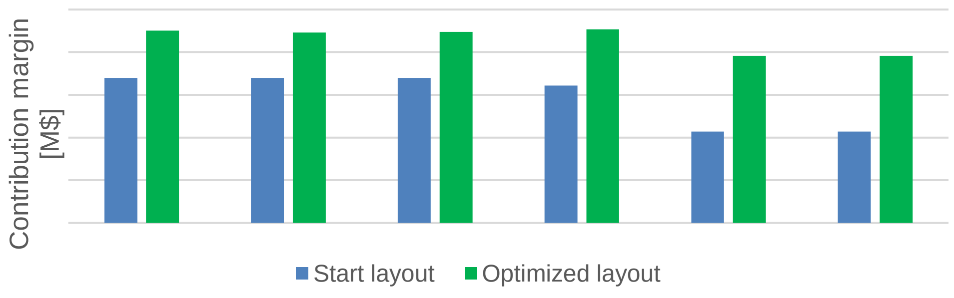
- Better solution is found by interlinking cost drivers and applying modern data science and optimisation methods to optimise the wind farm layout

- This significantly improves the project business case

Approach Sideshore

- Define parameters that vary spatially and have the most significant financial impact
  - Wake effects (& turbulence)
  - Foundation cost as function of water depth
  - Seabed preparation and soil related costs
  - Restricted areas such as archaeology, UXO and unfavourable water depths

- Optimise positions based on lowest cost considering all these variables
  - Define and integrate cost models for each parameter
  - Assume regular layout as reference
  - Optimise positions automatically with algorithms

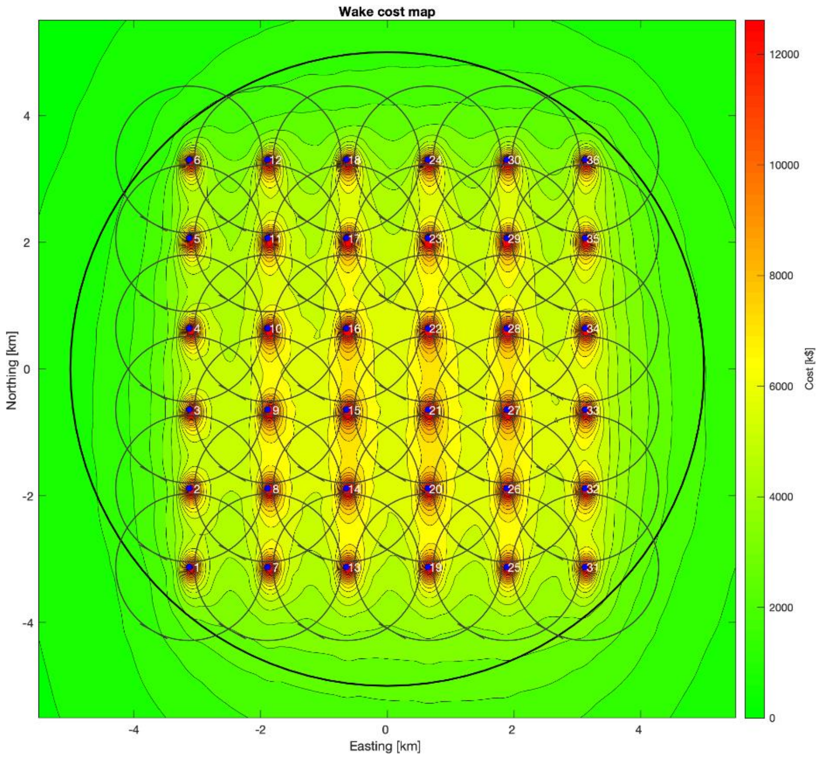


Confidential

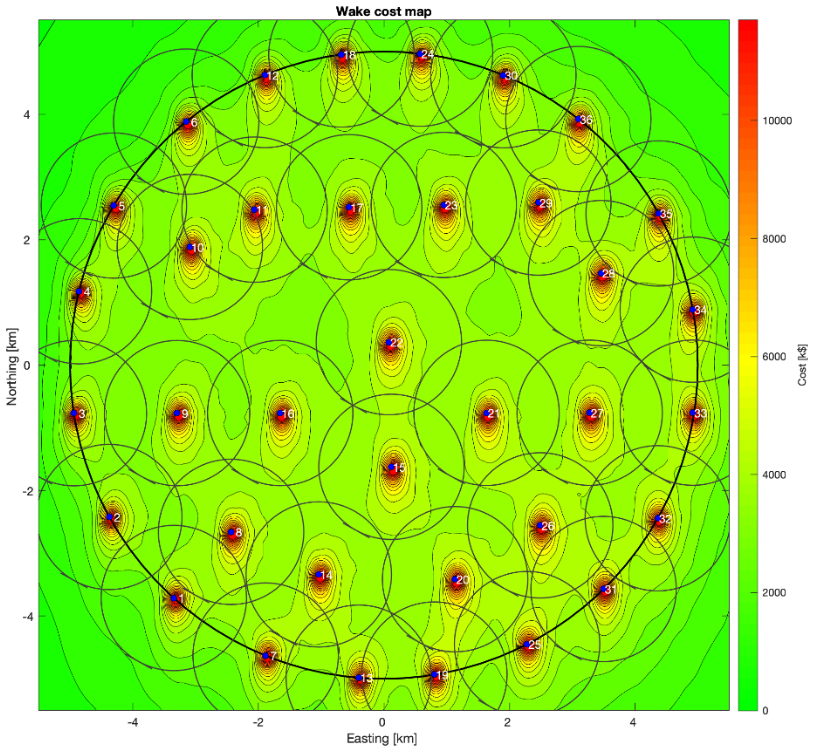
How our approach differs from others

- Often wind farm layouts are designed as a regular grid based on the prevailing wind direction
- **We optimise the layouts automatically, fully utilizing the buildable area**

Non optimized regular layout with high wakes

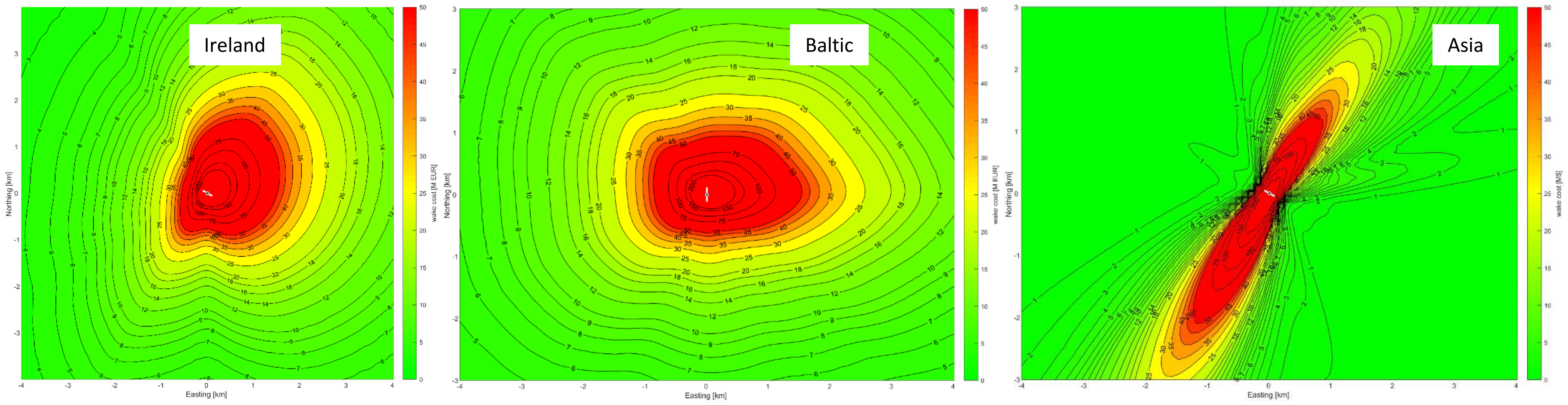


Optimized layout saving 50 million EUR NPV in wakes



How our approach differs from others

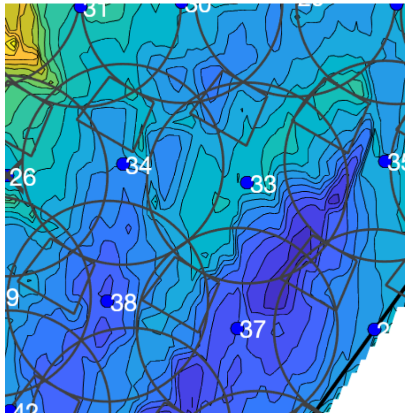
- Often wind farm layouts are designed as a regular grid based on the prevailing wind direction
- **We optimise the layouts using the actual wind distribution (not only prevailing dir)**



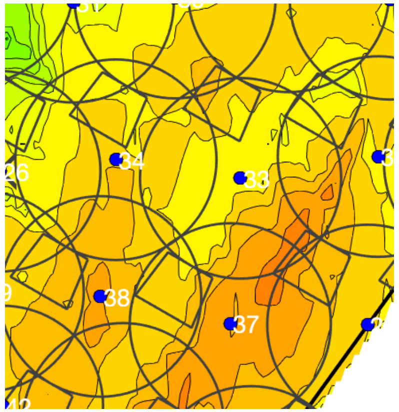
How our approach differs from others

- Often the impact of a wind farm layout on foundations and cables CAPEX is overlooked
- **We schematise a wide range of cost drivers whose sum of costs is optimized**
- **We are flexible to tailor our software to the project requirements**

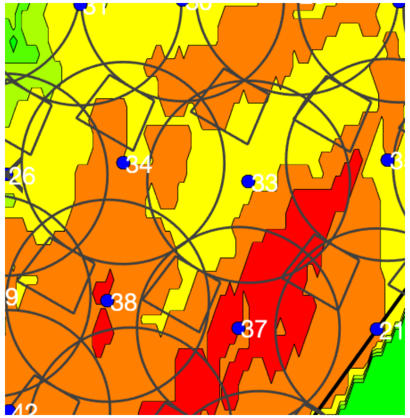
Water depth



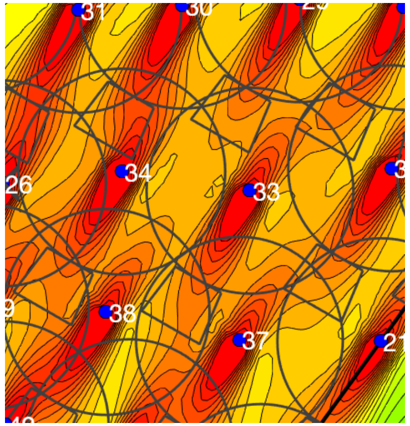
Foundation cost map



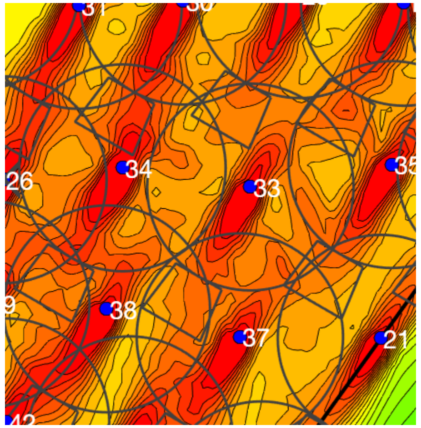
Depth cluster map



Wake cost map



Combined cost map



Unique selling points of Sideshore Technology

- Open-source layout optimisation
  - Freely available, developed by universities
  - Less user friendly (who will perform work?)
  - Less efficient coding (Python)
  - Limited optimisation options (no CAPEX, no GUI)

- Software providers
  - License fee, developed by commercial companies
  - Strong focus on wind resource assessment
  - Limited optimisation options (no CAPEX, only grids)
  - Limited tailoring to project (unique elements disregarded)

- Consultants
  - Limited to existing software capability
  - Less optimisation potential

- Sideshore: optimisation as a service
  - ✓ **User friendly: we optimise based on client requirements**
  - ✓ **We bring in highly specialised knowledge**
  - ✓ **Flexible to tailor software to project**
  - ✓ **GUI with flexible optimisation strategies**
  - ✓ **Automated optimisation**
  - ✓ **Various cost drivers included**
  - ✓ **Efficient coding → high resolution wake modelling and more iterations**
  - ✓ **WTG, cables and OSS included**

How does the process look like?

1: Data collection

- **Wind distribution** (typically from existing wind resource assessment or ERA 5)
- **WTG power & thrust curves**, power price assumptions, discount rate
- **Bathymetry and foundation cost** as function of water depth (if available), max. water depths
- **Restricted areas** such as archaeology, UXO and unfavourable water depths
- **Other cost drivers** (e.g. seabed preparation and soil related data (if available)

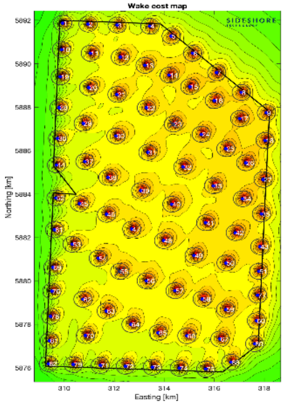
2: Scenario definition

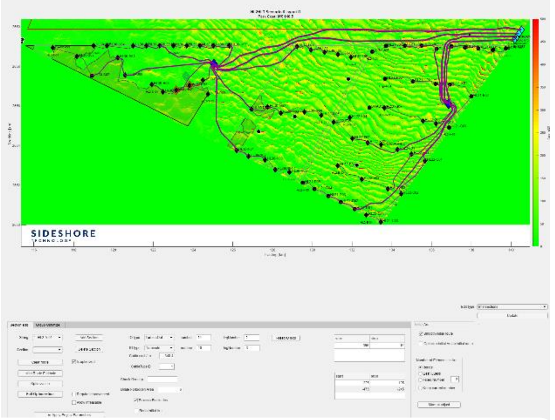
- Define a **base case** and **reference wind farm layout**
- Define **variants**
  - Different WTG model
  - Different spare turbines
  - Overplanting
  - Regular grid vs. irregular grid

How does the process look like?

3: Optimise the wind farm layout for each scenario

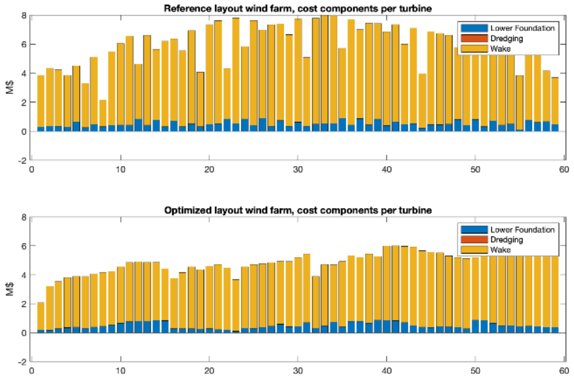
- Set up the **Layout Docter**
- **Present intermediate optimised layouts**
  - Yield & wake cost map
  - CAPEX cost drivers
  - Turbulence
- **Discuss the layouts** and finetune where needed





4: Reporting

- **Summarise** the results in a concise report
- **Assess** the achieved optimisations



Example of wind farm layout optimisation

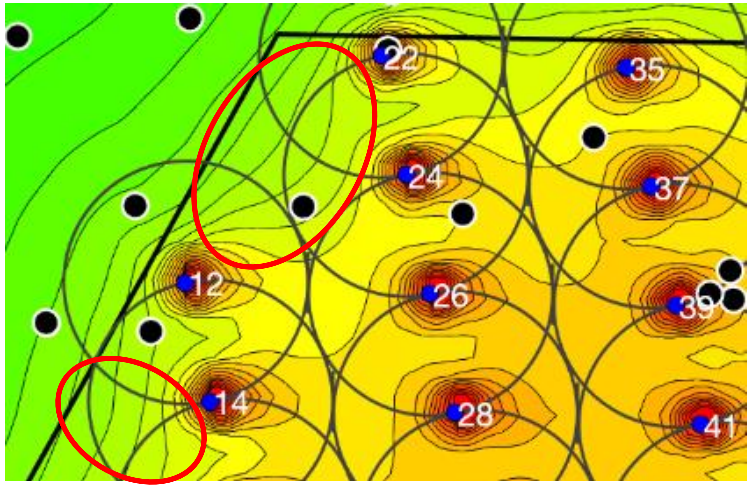
Developer with doubts about performance of existing regular layout

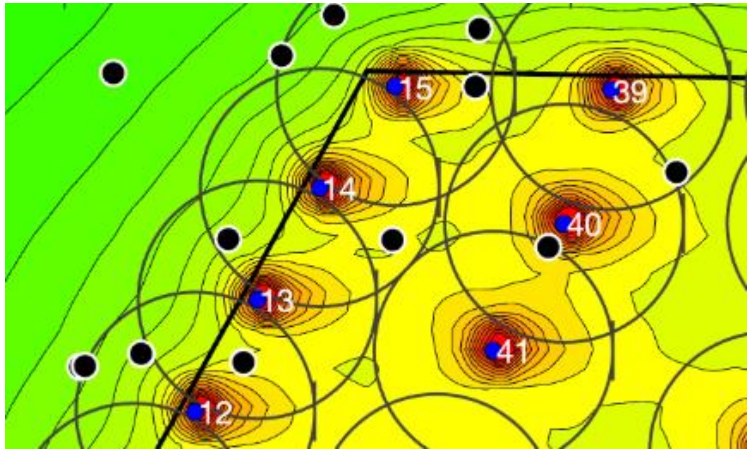
Test run showed that wake effects could be reduced from 10 to 8% using our software

We provided optimised layouts for various scenarios

Resulting layouts fully utilised the site

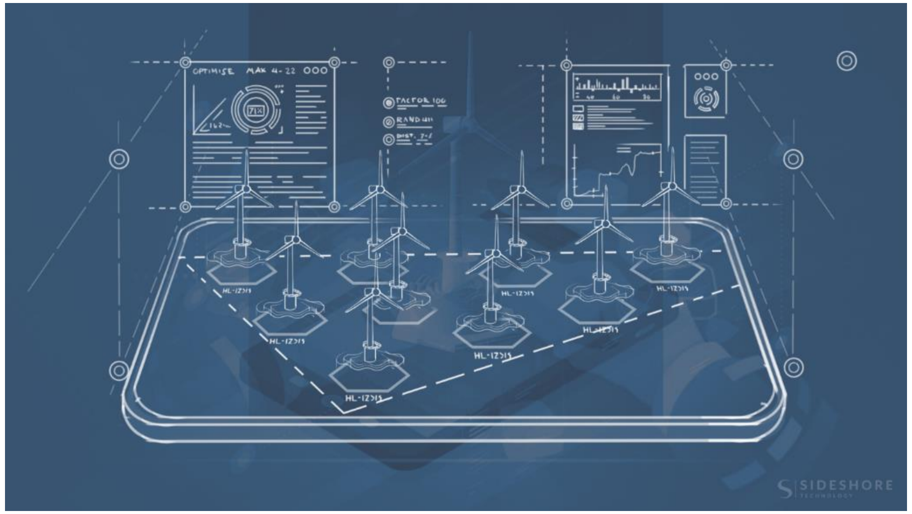
Cost savings estimated at 60 - 80 million EUR NPV





What do we optimise?

- Wind farm layouts
- Cable routes
- Offshore substation positions

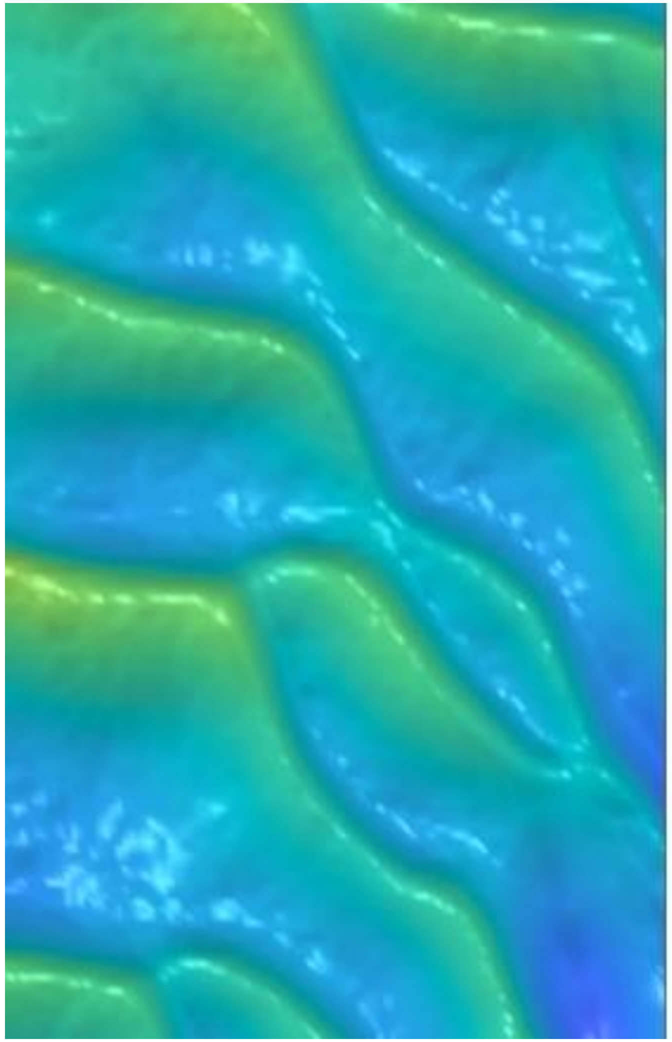


- … all based on a similar approach

Define cost drivers → Set up integrated model → Optimise positions

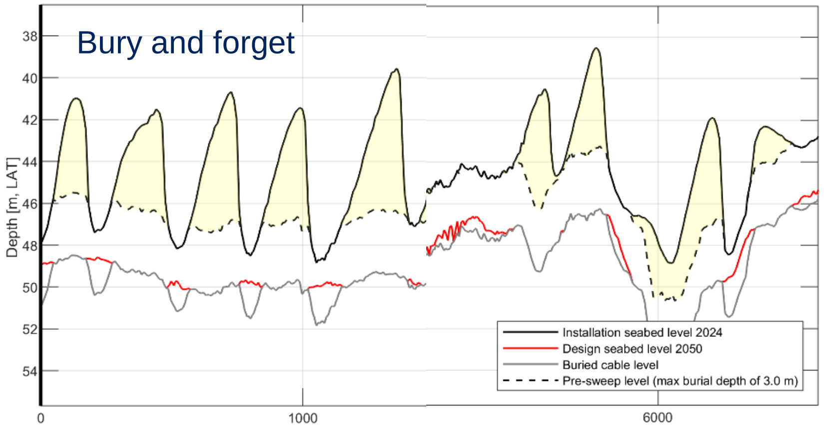
Part 2: Cable layout optimisation: case study

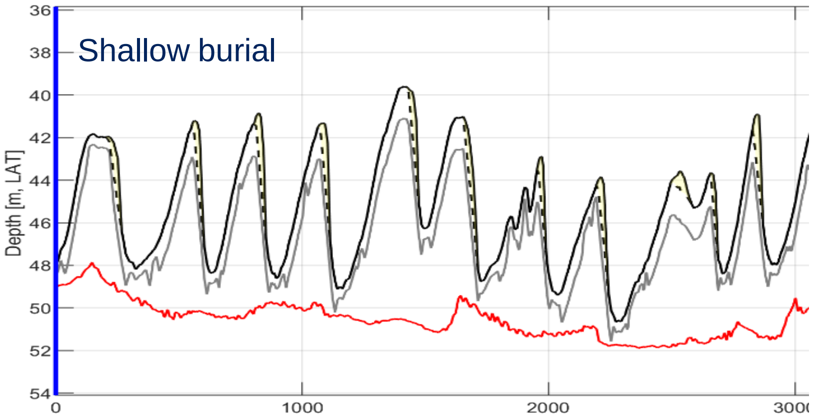
- Offshore wind farm in Asia
  - Site with strong currents and very large (8 to 10m), rapidly (20 to 40m/yr) migrating sand waves
  - Contractor was defining cable routes manually
  - Burial strategy (deep burial vs. maintenance) unclear
  - OSS locations defined based on “experience”
- Developer questioned whether this was most optimal solution
- SST executed test run for “pilot string”, which showed a significant potential for cost saving



Project: main cost drivers for cables

- Cable procurement and installation cost
  - EUR / m per section and cable type
- Cable loss
  - kW / m based on the electrical current and cable resistance (I^2xR) per cable type. Then convert to EUR.
- Two burial strategies considered
  - "**Bury and forget**": lay cable below lowest seabed, assume burial capability and dredge away tops of sand waves
  - "**Shallow burial**": peak shaving to make slopes gentle for installation, bury cables shallow and assume maintenance
  - Dredge volumes converted to EUR with unit rate
- Maintenance during operational phase
  - Required seabed prediction for each year of operation
  - Loop through all years and apply reburial where needed
  - Maintenance length converted to EUR with unit rate





Project: practical limitations

Installation requirements

- Minimum curve radius IAC type 1 -300mm2 Al
- Minimum curve radius IAC type 2 - 800mm2 Al
- Minimum curve radius IAC type 3 - 800mm2 Cu
- Minimum straight length at turbine
- Minimum straight length between curves IAC type 1
- Minimum straight length between curves IAC type 2
- Minimum straight length between curves IAC type 3
- Minimum distance between route and adjacent structure
- Minimum straight length of inter array cable at OSS
- Minimum distance between parallel inter array cables
- Any other installation requirements

Pre-sweeping

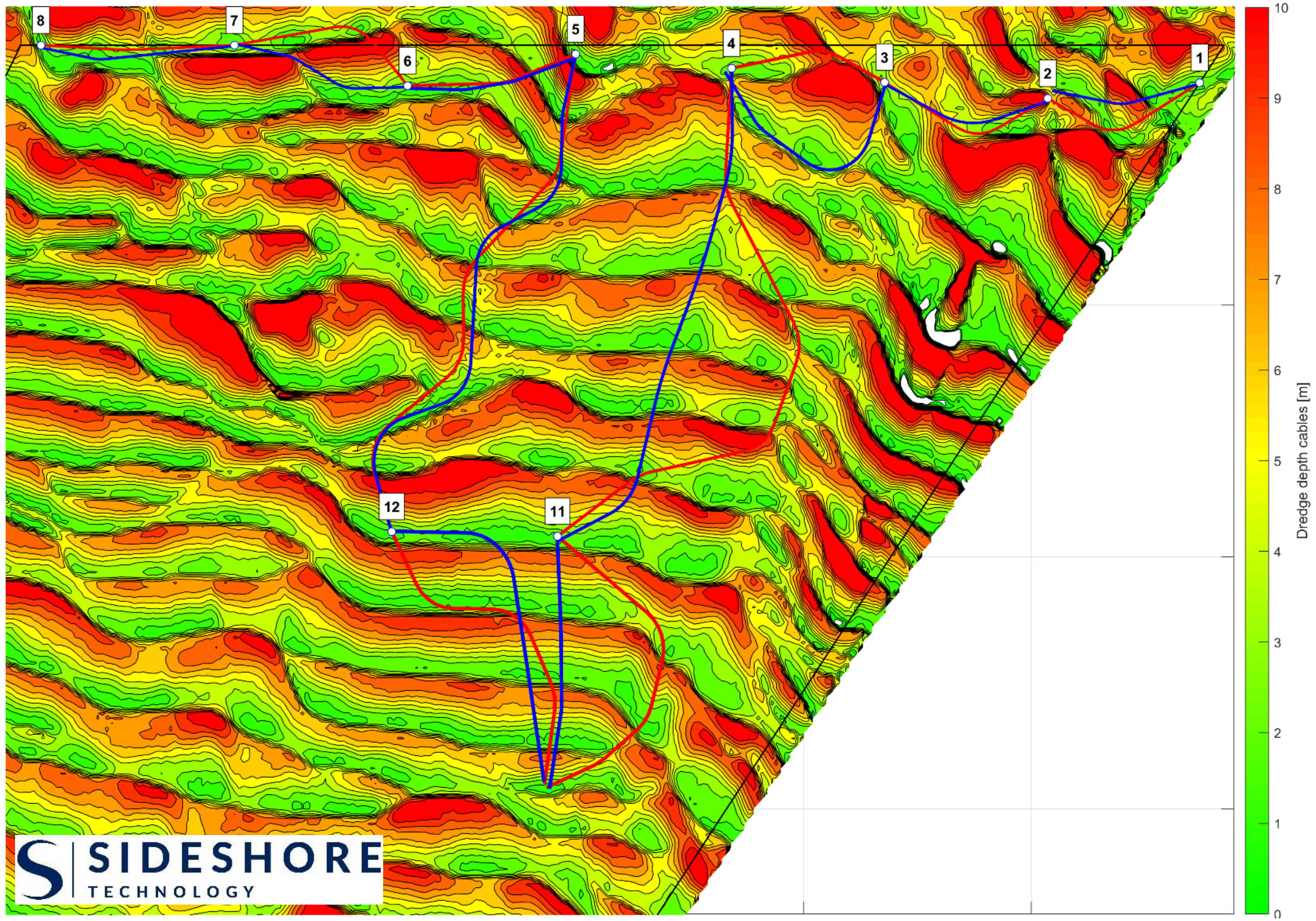
- Maximum Seabed Slope after peak shaving
- Installation Seabed Level
- Assumed cable burial depth w.r.t. Installation Seabed Level
- Trench width and side-slopes
- Maximum depth of trenching
- Year of inter array cable installation
- Pre-sweeping cost per m^3
- Dredging over depth (all cases)

Maintenance

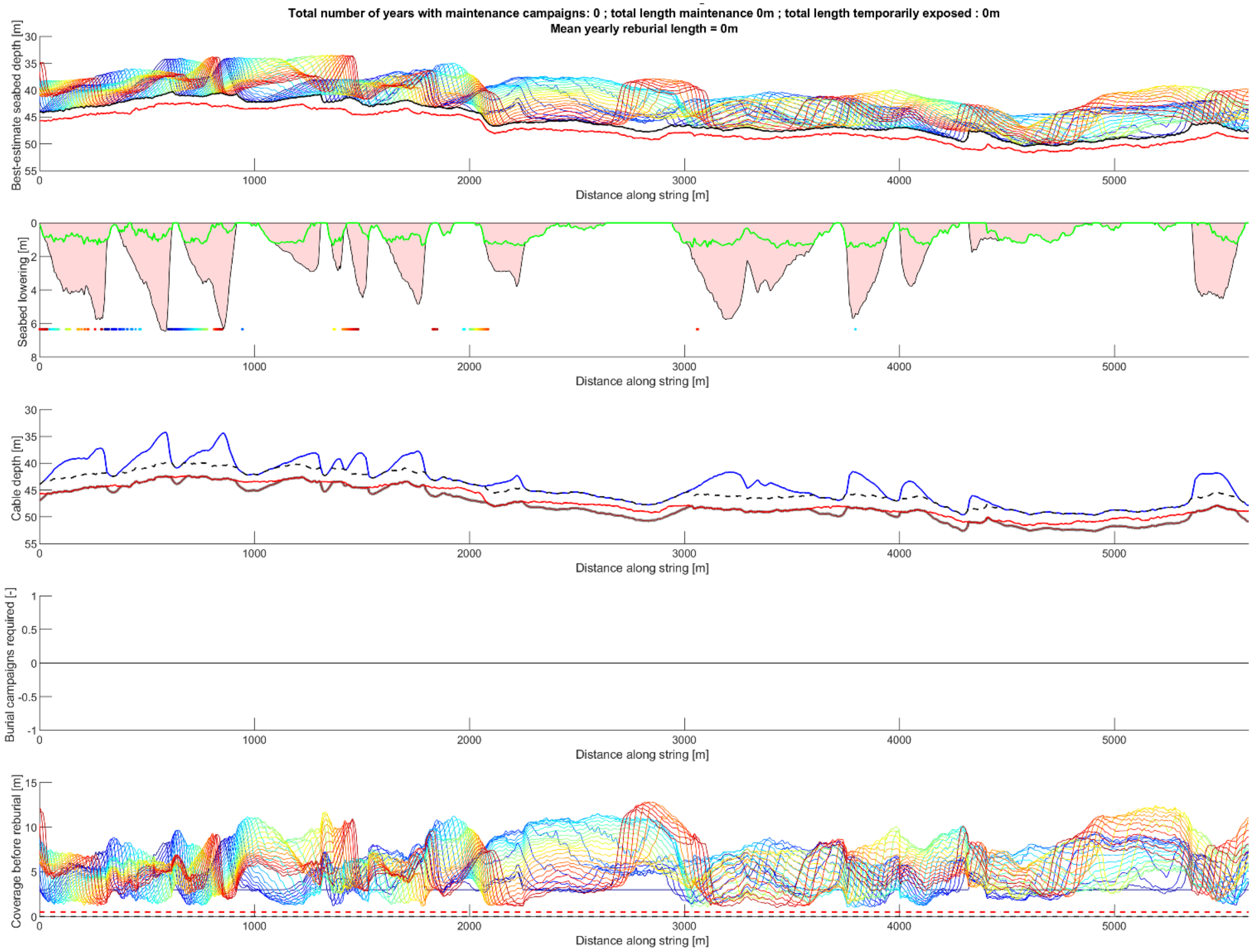
- Best-estimate seabed levels on a yearly basis
- Initial burial depth
- Reburial depth. This is the DOL when performing maintenance
- Minimum coverage threshold before performing maintenance
- Maintenance costs
- Maximum allowed number of reburials from cable integrity perspective

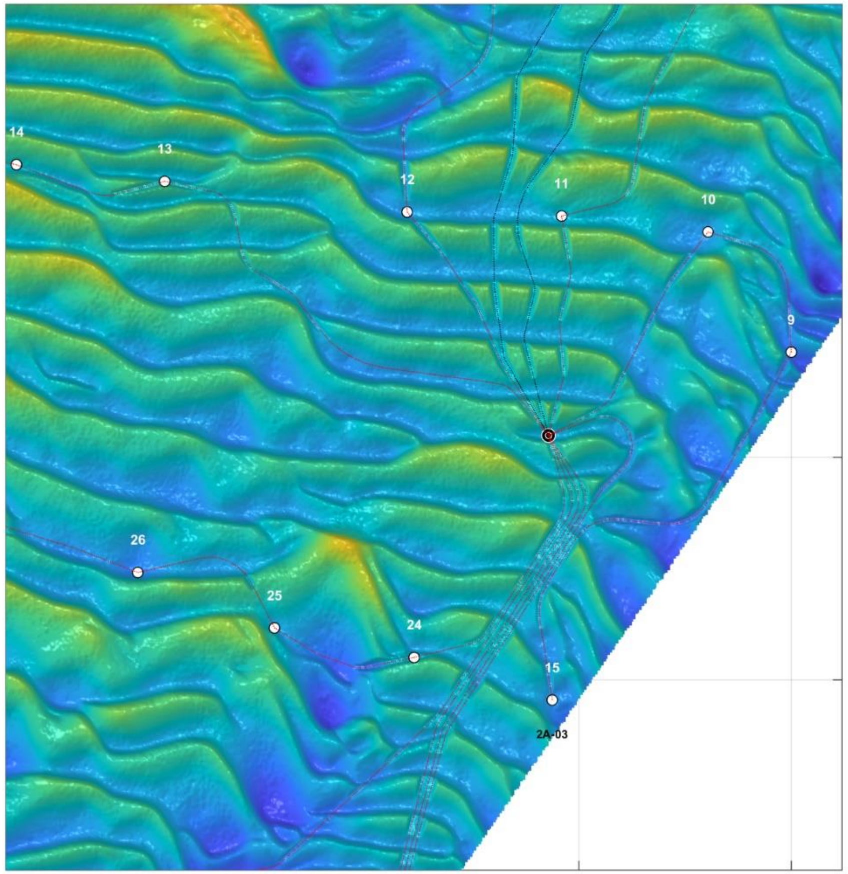
Project: how did the cost drivers influence routing?

- Cable procurement and installation
  - Aims for minimum length
- Cable loss
  - Aims for minimum length
- Dredging
  - Aims to avoid sand waves
  - Cables in troughs of sand waves
  - Cross sand waves as perpendicular as possible
- Maintenance
  - Similar to dredging
  - Lower influence

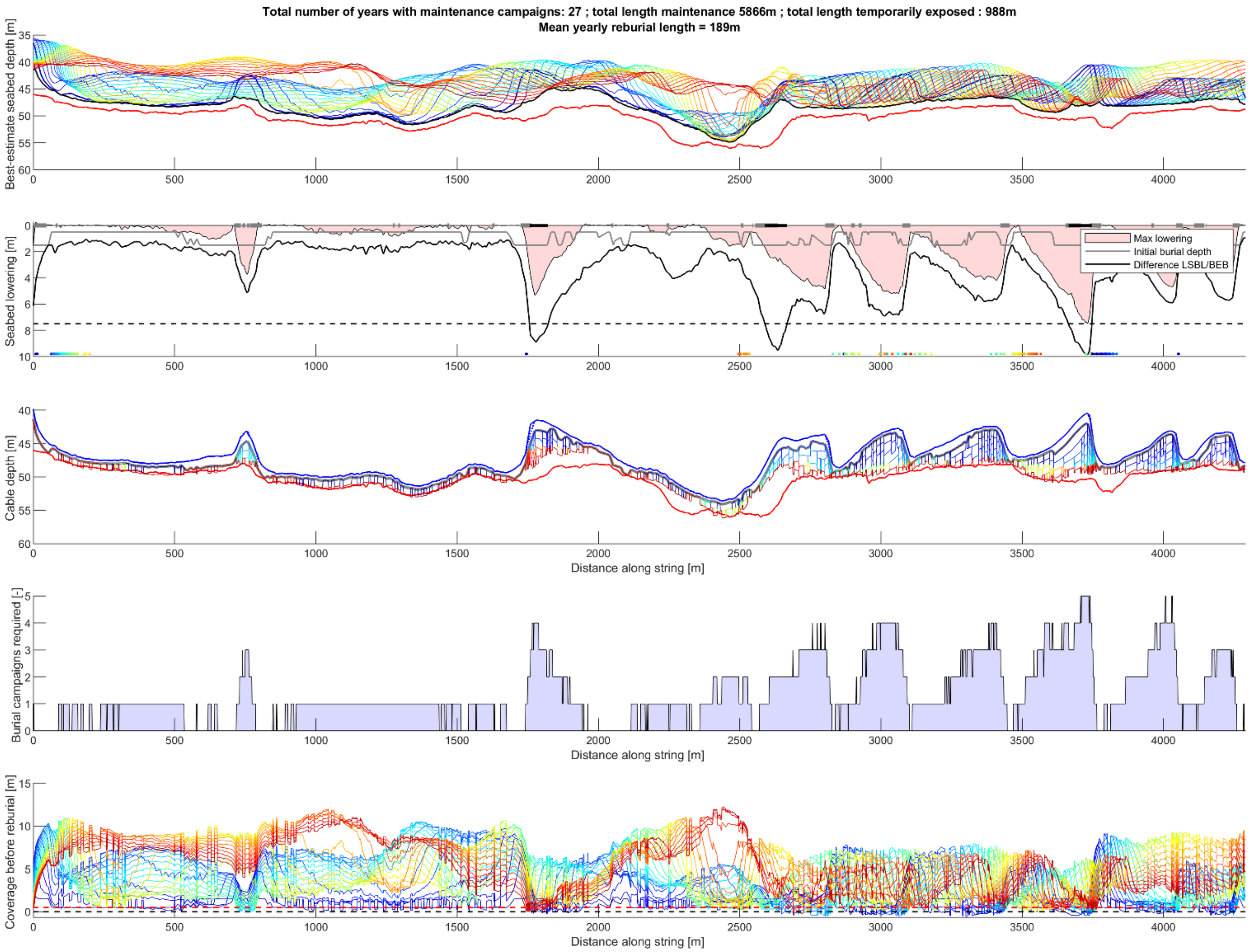


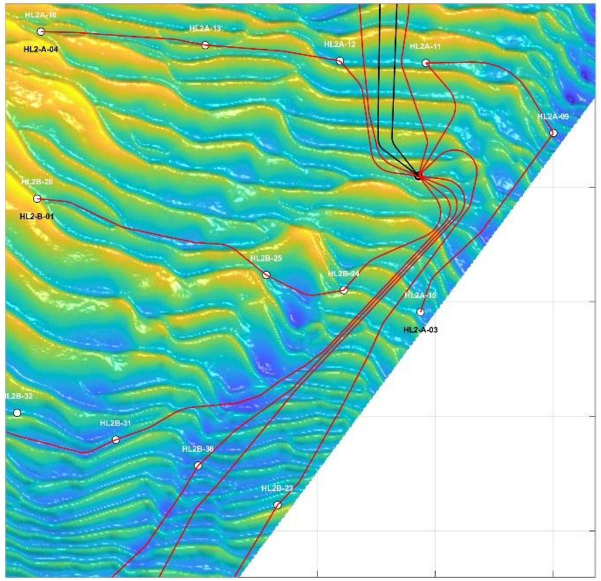
Project example of “Bury and forget” optimisation

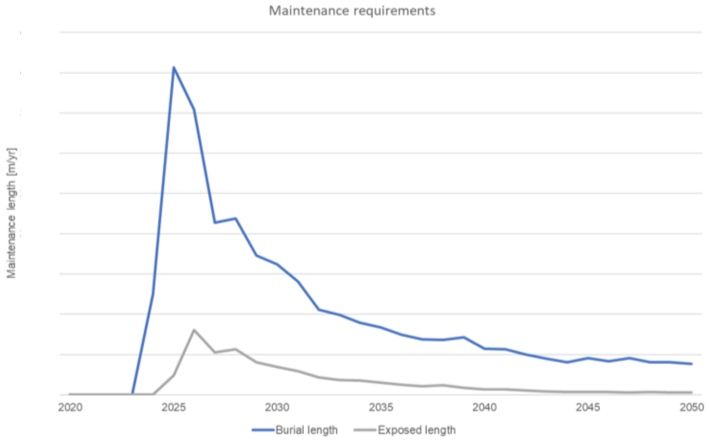




Project example of Shallow Burial with maintenance



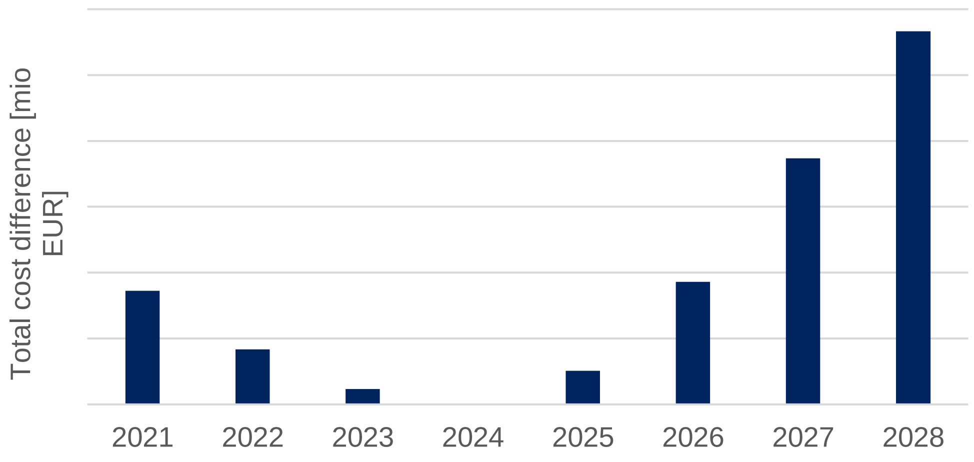


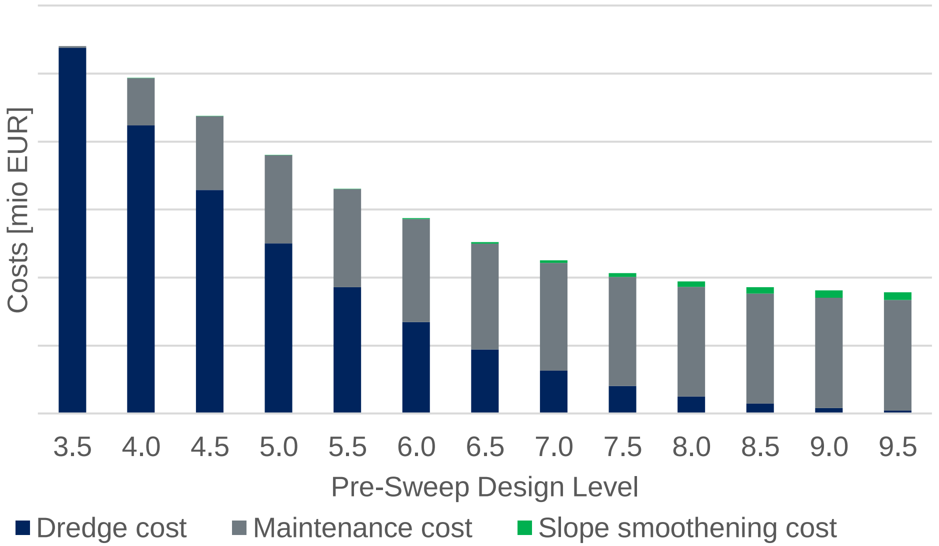


Project sensitivities considered

- Sand wave speed
  - What if sand wave speeds is quicker or slower?
  - What if installation is postponed with a year?
  - Routes not that sensitive for a change of +/- 1 year

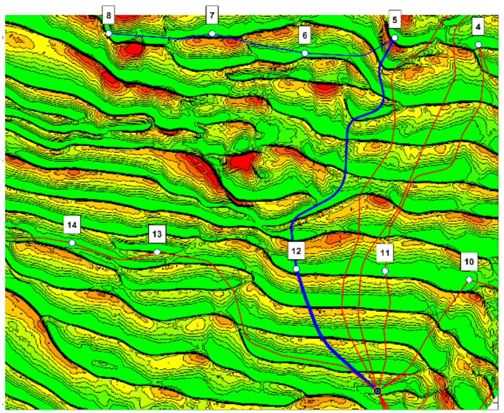
- Burial depth
  - For a given set of routes, who do the costs change if the burial depth is changed
  - Different burial strategies compared and costs calculated
  - Lower costs for shallow burial (although this requires yearly maintenance and poses risks of cable exposure)

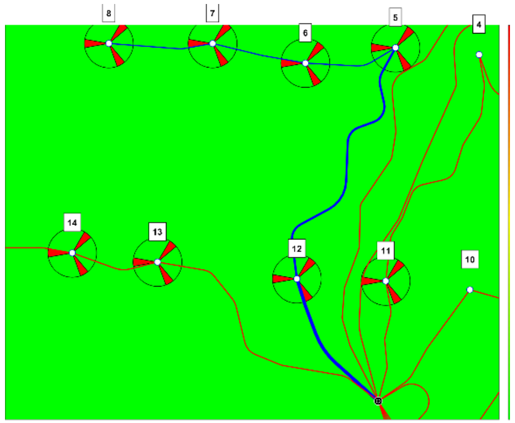


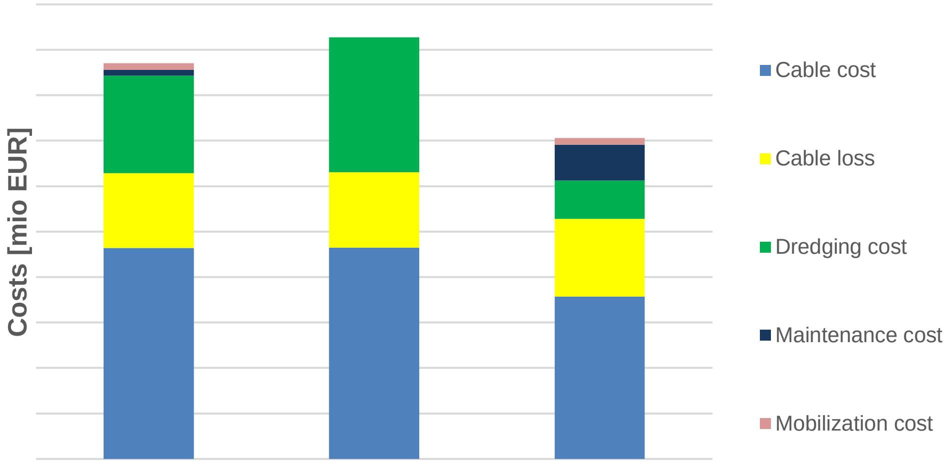


Project conclusions

- Finally achieved cost savings are significant
- Routes generated by automation process intuitively make sense
- Various advantages compared to manual routing
  - It is easy to make changes to assumptions and rerun
  - Various scenarios (e.g. burial strategies) can be evaluated and quantified
  - Various sensitivities can be checked (e.g. sand wave migration rates)
- This approach has particular added value in complex areas (e.g. with sand waves) or with combined OSS / turbine / cable optimisation

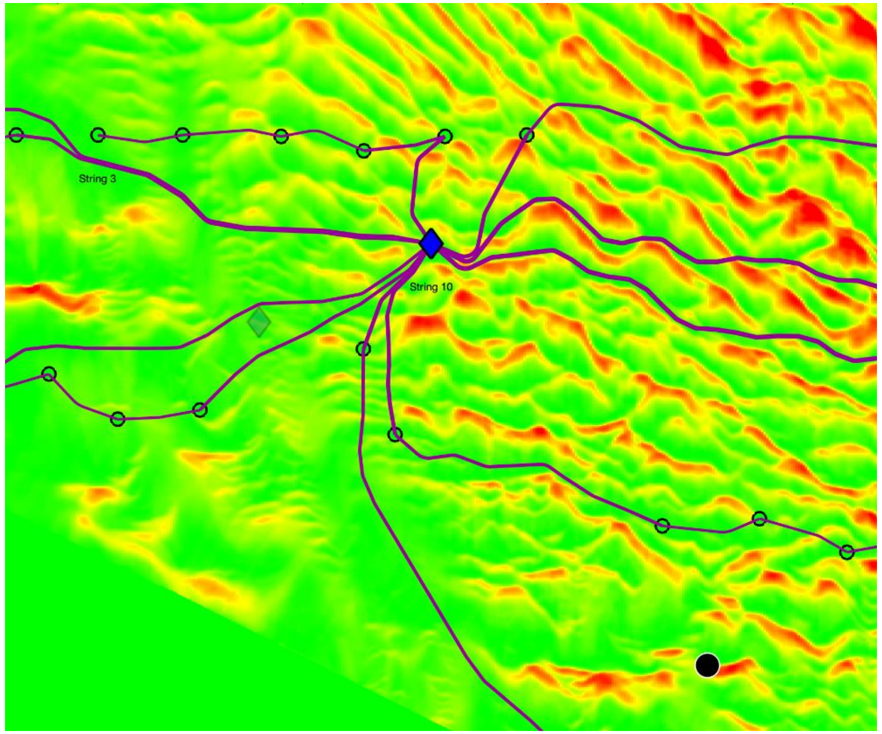






Part 3: OSS position optimisation

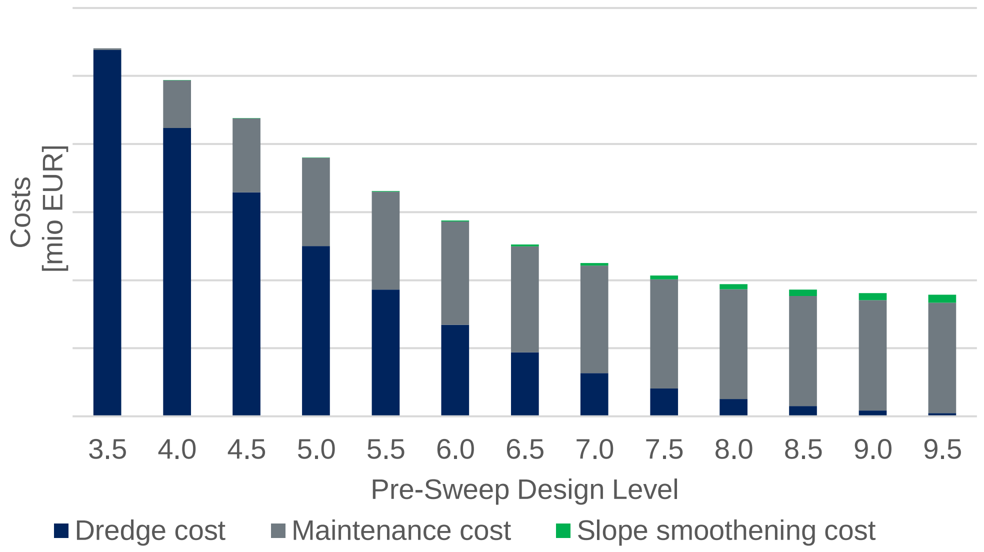
- All cost drivers for the OSS, export and infield cables were fully schematized (procurement, losses, dredging, foundation cost)
- OSS position was optimized by moving the OSS, rerouting cables and recalculating all costs
- Significant cost savings

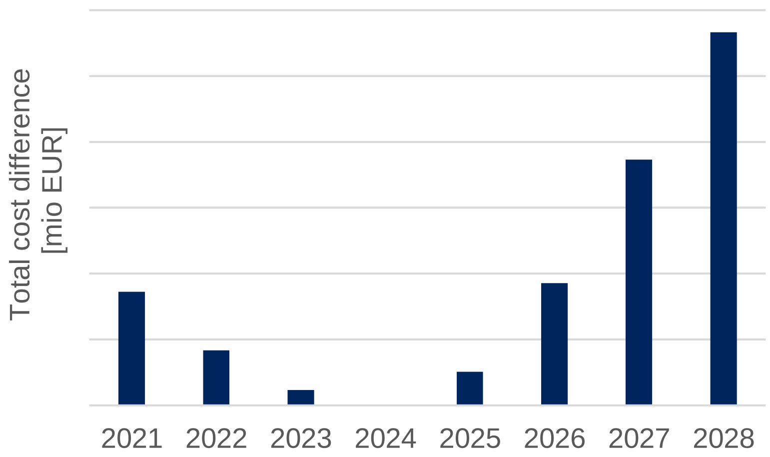


What is the key value of using algorithms?

Building a model takes time… but

- ✓ Automated optimisation provides significant cost savings
- ✓ All relevant cost drivers interlinked in a single model
- ✓ Different strategies and boundary conditions are easily assessed (turbine models, burial strategies)
- ✓ Quantified sensitivity analyses





We look forward to working with you!

SIDESHORE
TECHNOLOGY

Founders

Ben de Sonneville

- Qualifications
  - MSc Civil engineering @ Delft University of Technology (cum laude)
  - 10 years of experience in offshore engineering & programming (Deltares)
  - 5 years of experience in offshore wind project development (BLIX, Sideshore Consultancy)
- Typical role
  - Project manager, main contact
  - Prepare input & output for projects
  - Reporting

Jan van der Horst

- Qualifications
  - MSc Applied Physics @ Delft University of Technology
  - 15 years of experience in technology management & development (Philips, Dimenco)
  - 2 years of experience in offshore wind projects (Sideshore Technology)
- Typical role
  - Algorithm research & development
  - Preparing and implementing cost models
  - Execute layout optimization

Our track record

- Wind farm layout optimisation
  - ✓ 7 wind farms optimised
  - ✓ 5 early-stage development
  - ✓ 2 detailed layout optimisations
  - ✓ 5 in Asia, 2 in Europe
- Cable and OSS optimisation
  - ✓ 2 full detailed cable and OSS optimisation
- Cost savings achieved
  - ✓ 290 million EUR in project value saved so far
- Our clients