INTEGRATED PROJECT LOGISTICS AND COSTS CALCULATIONS FOR GRAVITY BASED STRUCTURE

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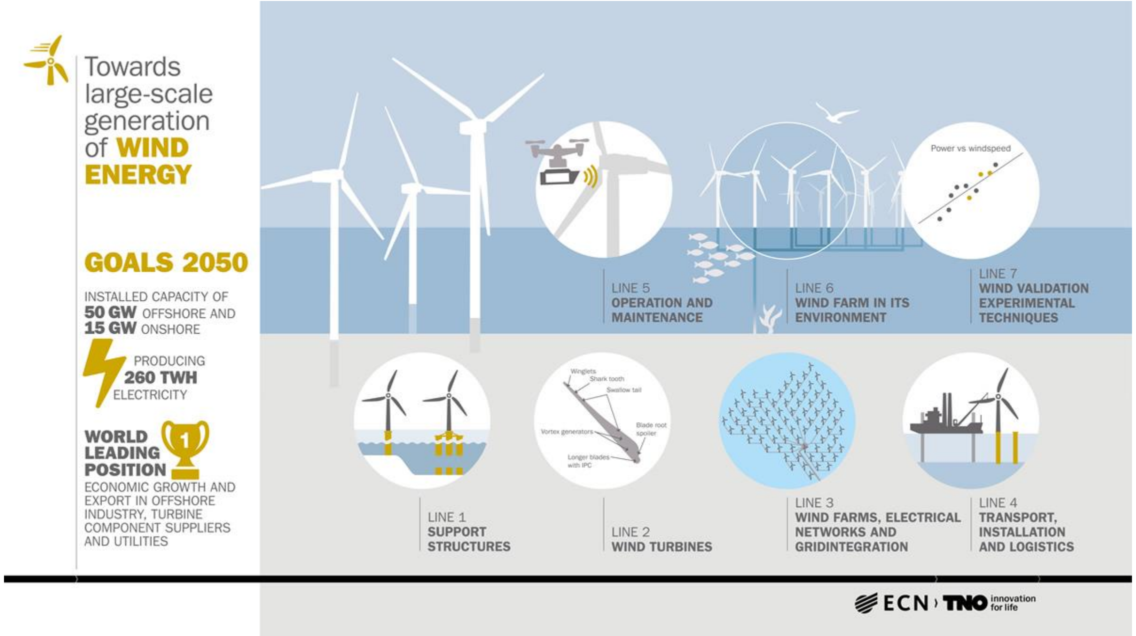
ECN › TNO innovation for life

AGENDA

- Introduction & Motivation
- Installation modelling and simulation
- Case studies of different GBS (installation) strategies
- Optimization opportunity
- Results and recommendation

TOWARDS LARGE-SCALE GENERATION OF WIND ENERGY



GBS AS LARGE OFFSHORE WIND TURBINE FOUNDATION

- Alternative for jacket & monopile in deeper water
- Experience in oil and gas and civil engineering
- Provide designs of GBS for offshore wind large WT
- GBS for wind needs to be transported and installed in rough sea condition

- **Better understanding** is needed to **reduce costs** and **risk** to make offshore wind with GBS **economically viable**

- GBS JIP consortium
  - Marin, Deltares, Witteveen + Bos and Vuyk Engineering
  - Deme, Besix, Saipem, Jan de Nul, Statoil, Strukton, Bureau Veritas, ALP Maritime and MonobaseWind

Source: Van Oord

OUTLINE OF THE WORK

- Step by step description on constructions, transports and installations operations for GBS
- Cost of energy analysis

- Insight into:
  - Cost drivers for LCOE using GBS as foundation (construction, transport, installation)
  - Logistical (time) plan and how to optimize them
  - Resources (material, equipment, technician, harbour) requirements
  - Weather restrictions

ECN PART OF TNO IO&M VISION

Strategic Simulation Tools

for

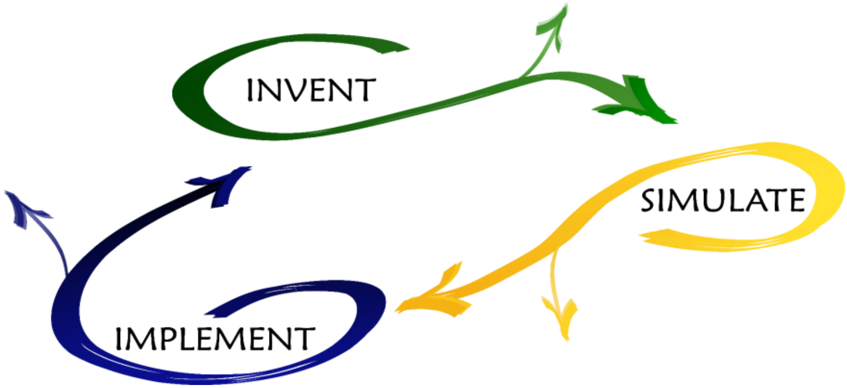
Optimal Decision Making

in

Offshore Wind Farms

WHY BUILD COMPUTER MODELS?

**Simulations (re-)create, as exactly as possible,
time series (from history or for future possibilities),
considering causes and effects**



**Computer simulations are <u>safe</u> and <u>low cost</u>,
compared with the real world**

ECN INSTALL

Needs of installation modelling tool

- Design and optimize the installation strategy for an offshore wind farm
- Determine project planning, delays, costs and risks
- Monitor progress during installation

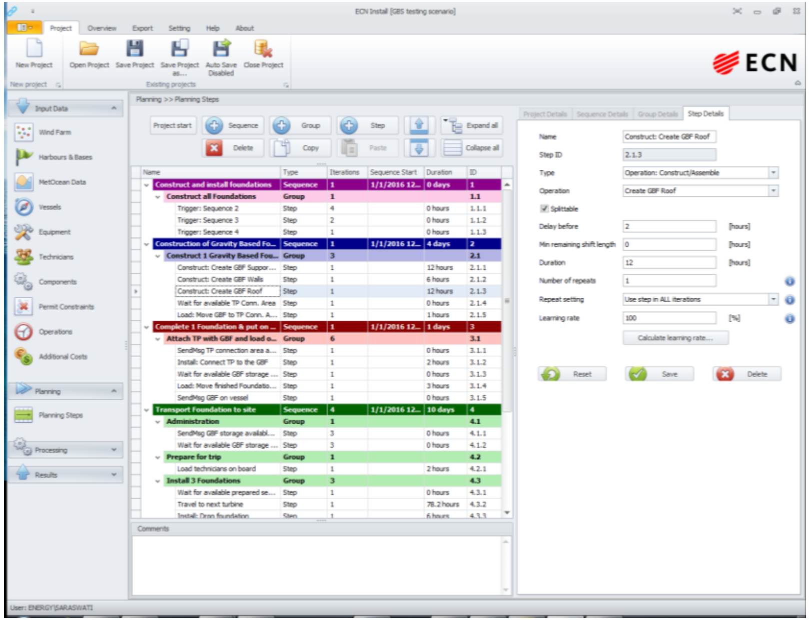
Source: Gemini

Commercial proof / Evaluation

- Installation methods
- Support structures & wind turbines
- Vessels and equipment

Source: Royal IHC

ECN INSTALL: HOW IT WORKS



- Input/Simulation
  - Deterministic discrete event simulator with historic weather data
  - Planning using intuitive operations
  - Multiple actors (vessels, equipment, group of technicians) per operation
  - Weather window and weather restrictions
  - Learning curve

- Result
  - Installation costs, installation planning, resources utilization and installation delays
  - Excel and graphical

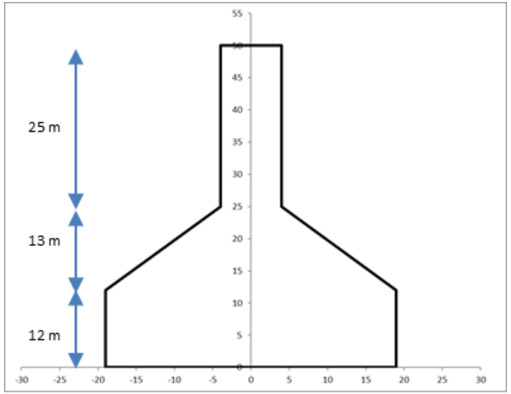
CASE STUDY

- Location: Borssele area
- 60 x 10 MW
- Construction & installation port: Damen Verolme
- Wind turbine installation port: Port of Esbjerg

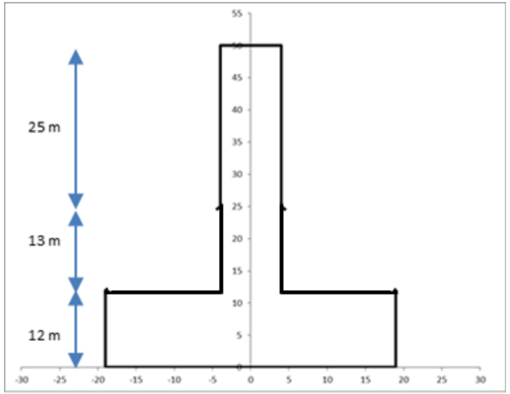
- 3 GBS concept designs compared

- ECN Install simulation:
  - Onshore construction and assembly for GBS
  - Load out, transport, and installation operation (entire wind farm)

GBS DESIGN FOR 10 MW TURBINES



Parameters	unit	value
Diameter base	[m]	38
Diameter of shaft	[m]	10
Total model height	[m]	50
Min draft	[m]	9.7
tow draft	[m]	8.6
Dry weight	[t]	11200



Parameters	unit	value
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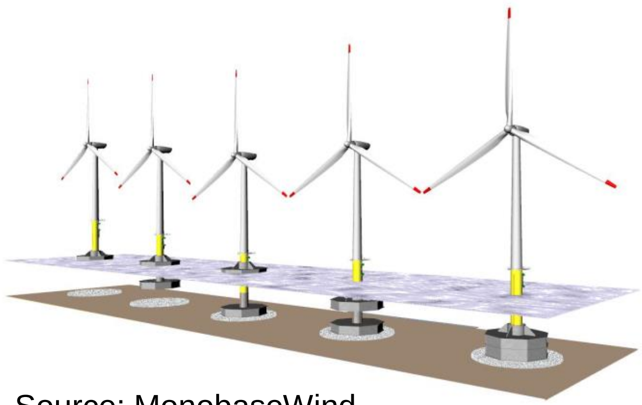
Height of base	[m]	12
Height of cone	[m]	13
Diameter of shaft	[m]	10
Total model height	[m]	50
Dry weight	[t]	7240



Source: MonobaseWind

Parameters	unit	value
Diameter base	[m]	45.5
Height of base+foot	[m]	12
Min draft	[m]	9.5
tow draft	[m]	8.6
Dry weight	[t]	12000

COST COMPONENT CONSIDERED

- Construction

Material requirement → Steel works → Equipment → Cranage → Construction costs and site rent → Profit, contingency, etc.

- Marine Operations

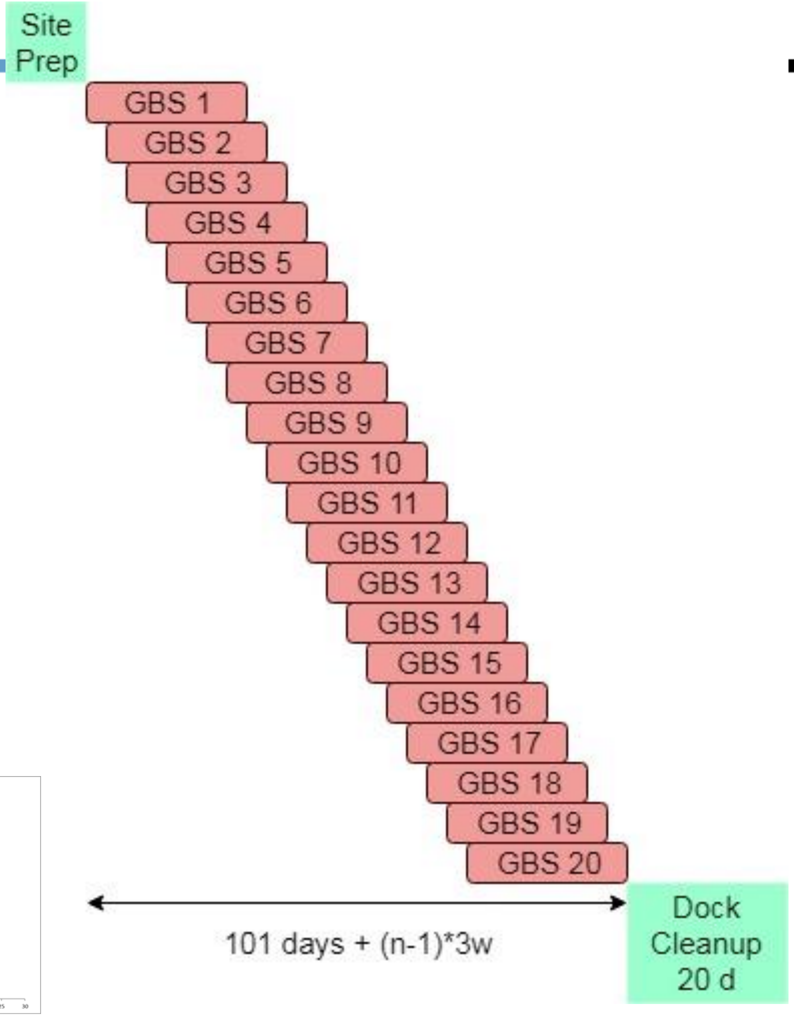
Seabed Preparation → Foundation Transport and Installation → Parallel
- BOP (OHVS + Export Cable) Installation
- Scour Protection

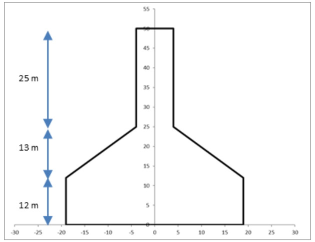
→ Infield cable laying & burying → Wind Turbine Transport & Installation (except case 3) → Commissioning

- Other LCOE components (OPEX, power production, other CAPEX costs *components costs and their installation costs)

FLOATING GBS

- Constructed in dry dock (batch 20 GBS)
- Advantage:
  - Easy to load out, store
  - Cheap marine logistic (tug boats, ballasting vessels)
- Challenges:
  - Long construction time (~1 year/batch)
  - High costs dry dock
  - Higher risk (delay caused by one GBS)





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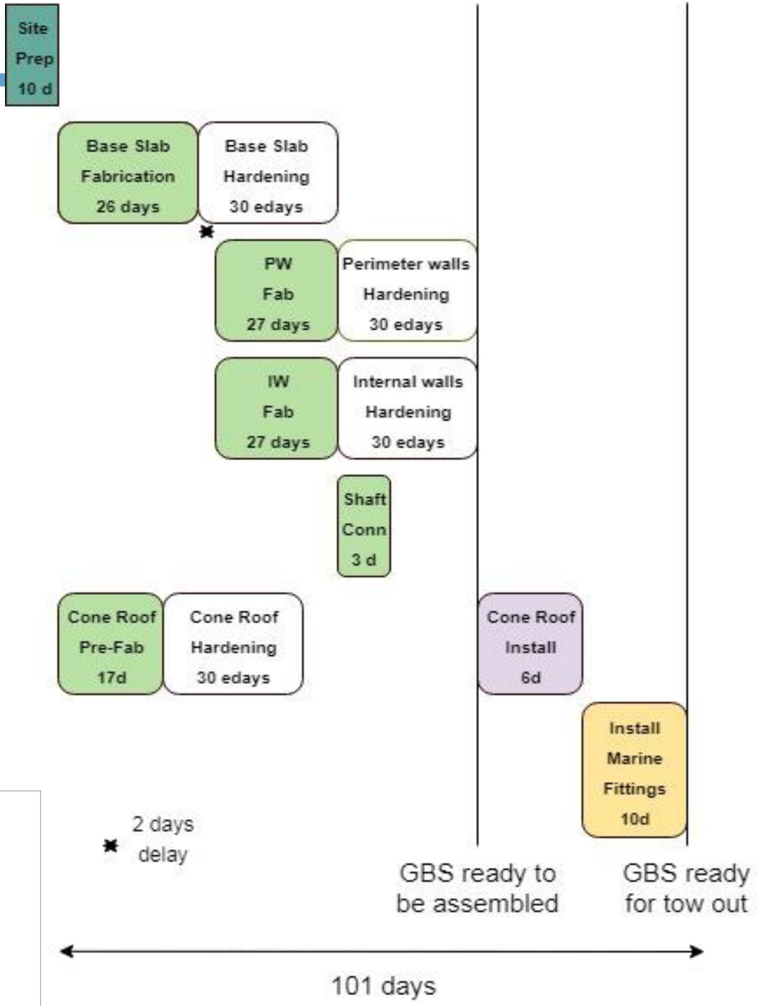

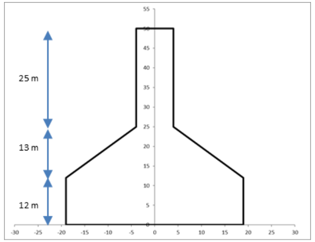

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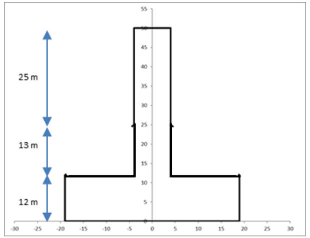
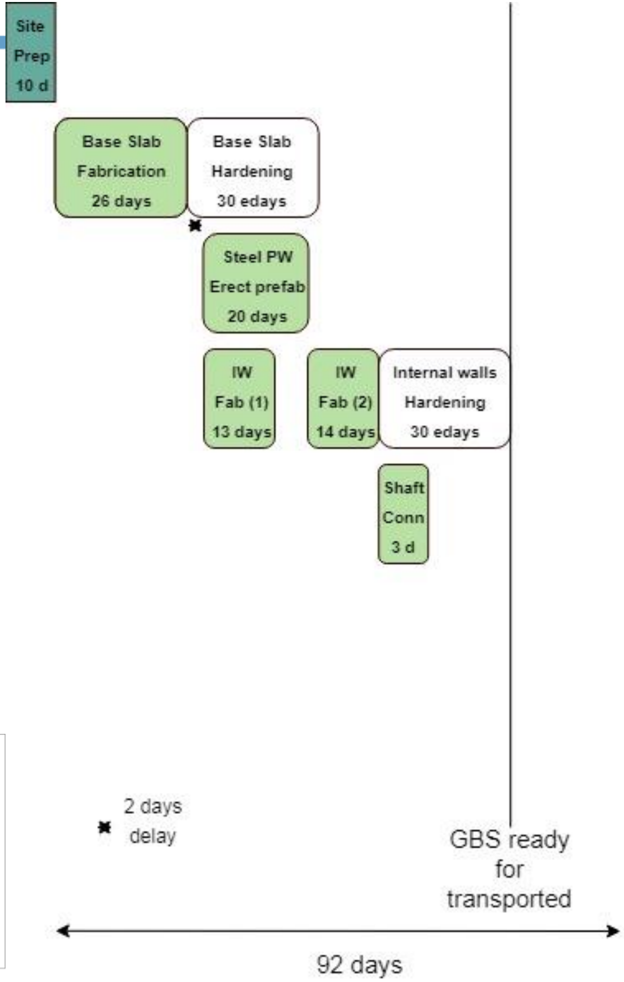
Source: Van Oord

NON-FLOATING (LIFTED) GBS

- Constructed in quay side
- Advantage:
  - No batch time
  - Flexible construction site
- Challenges:
  - Still long construction time
  - Expensive heavy lift vessel (>7300 tonnes)





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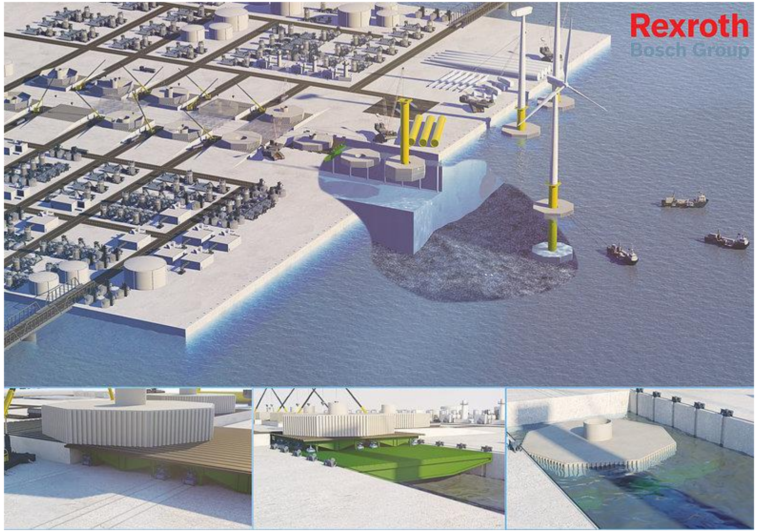
Source: Jan De Nul

INTEGRATED GBS (PRE-INSTALLED TURBINE)

- Constructed in dry dock
- Advantage:
  - Faster construction time than other designs
  - Less operation offshore and cheap marine logistic
- Challenges:
  - Higher weather restriction (tug boats, turbine)
  - High man-hours required for construction



Source: MonobaseWind

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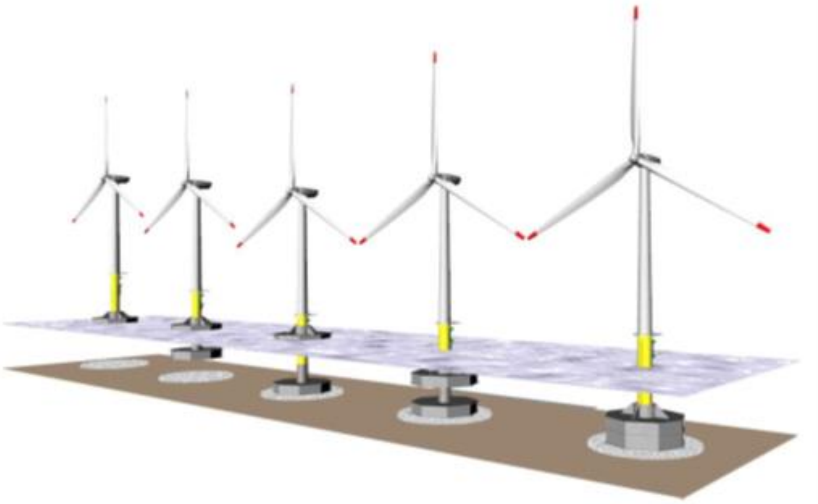
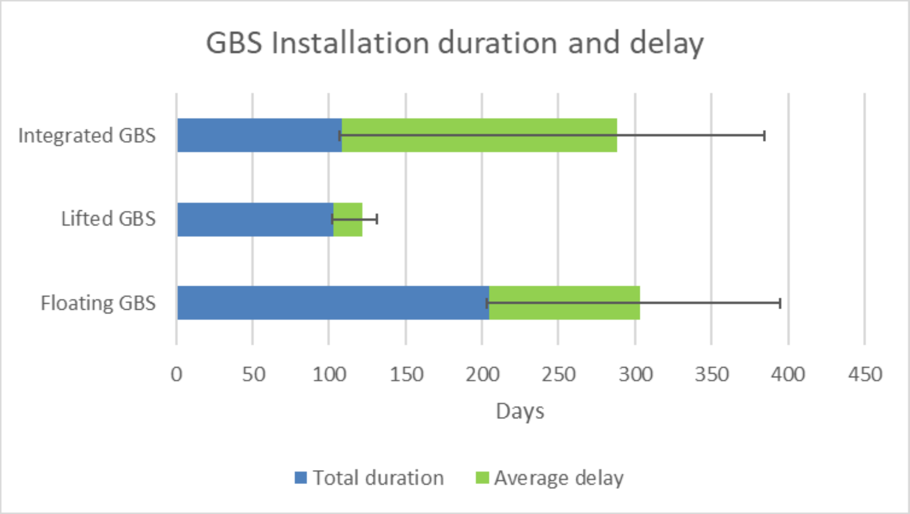


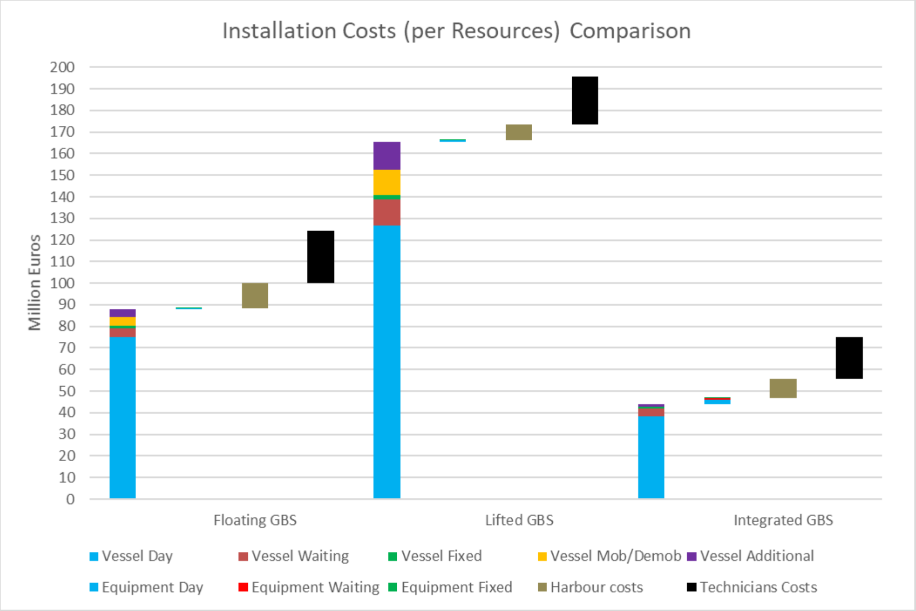
Source: MonobaseWind

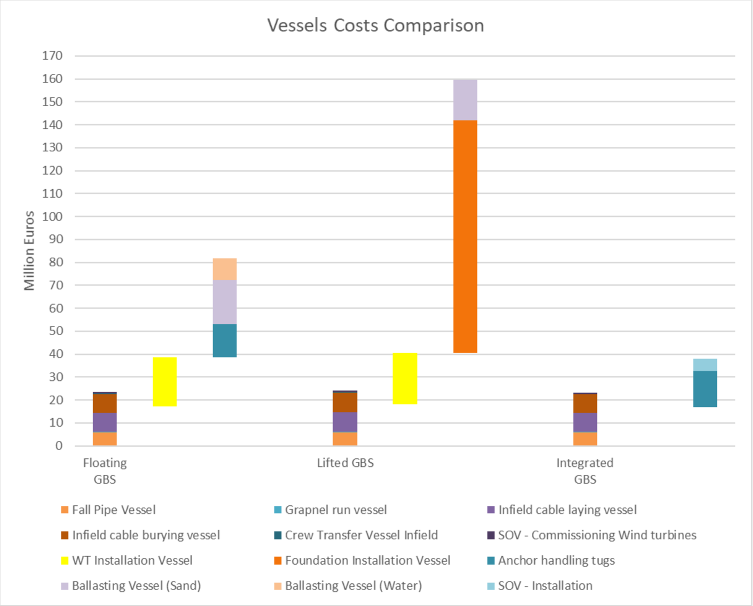
MARINE OPERATION PLANNING

- One load out at a time
- Winter is avoided
- Case 1 & 3 are commissioned within 2 years



COSTS



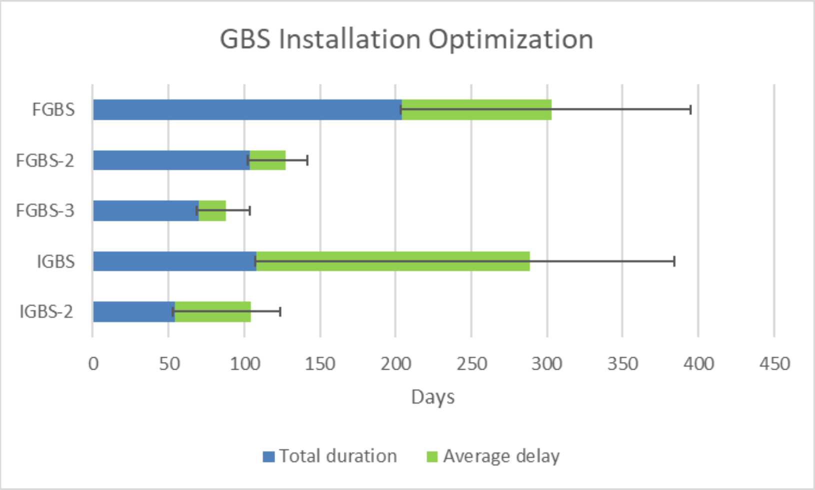


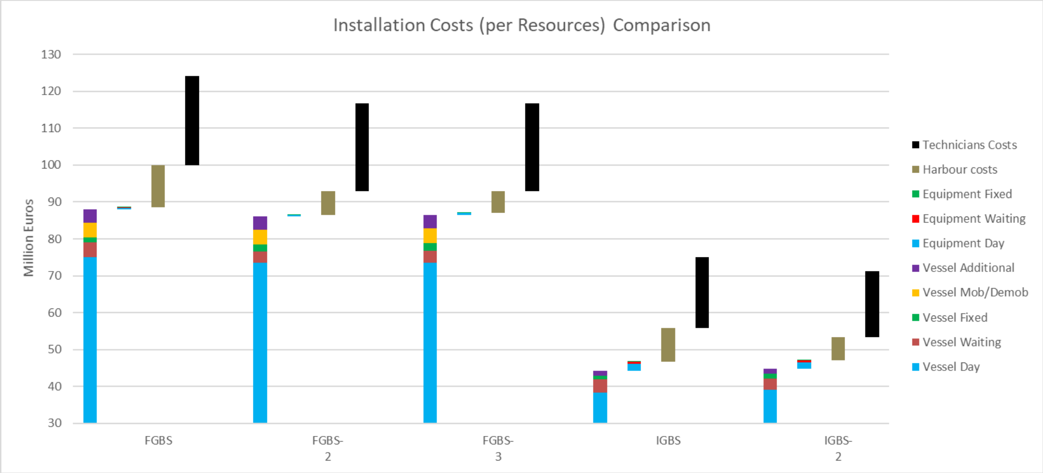
- Vessels used for all cases → 23 M€
- Wind turbine installation vessel → 21 M€

OPTIMIZATION OF INSTALLATION PLANNING

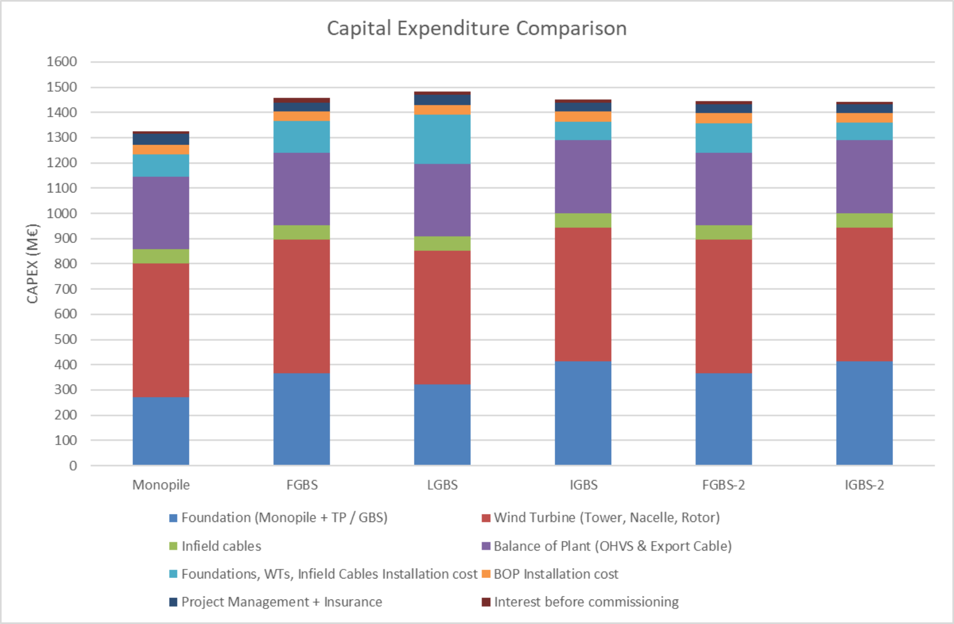
- Least delay → April – September
- 2 load out at a time
- Reduction in installation costs:
  - Floating GBS: 6% → 7,5M€
  - Integrated GBS: 5,3% → 4M€

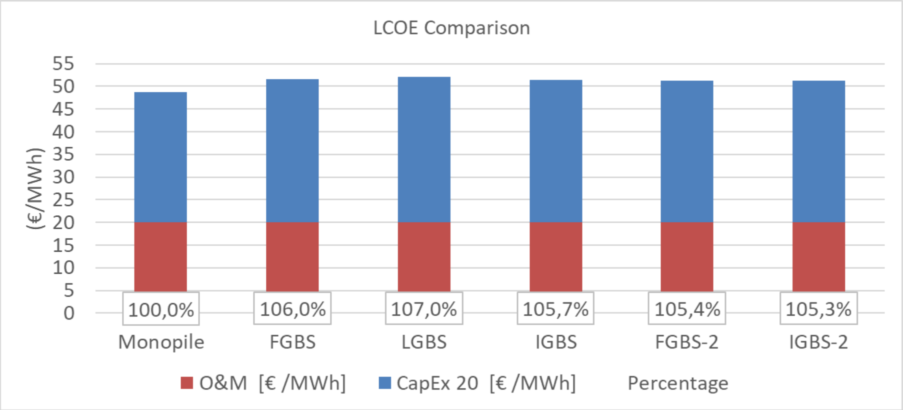
- 600 MW wind farm can be commissioned within 1 year!





CAPEX COMPARISON TOWARDS LCOE





- LCOE GBS cases are slightly higher compared to monopile (5-7%)

CONCLUSIONS

- GBS Construction
  - More GBS per batch has higher risk (drydock). A delay of one of the GBS will impact the whole batch and increase the total construction costs.
- Offshore Installation
  - GBS offshore operation is long due to the low speed of towing, extended installation operations with limited weather windows → Optimization needed
  - Transport and installing GBS with heavy lift vessel is fast but the costs are high
  - **Lowest installation costs: Integrated GBS – Floating GBS – Lifted GBS**
- Potential reduction
  - Higher workability for the longer operations, such as towing, water ballasting and sand ballasting
  - Installation is only done within favourable seasons (April – September)

RECOMMENDATIONS

- GBS Construction:
  - Reducing the costs of GBS construction; the direct material costs and then the costs of the construction site (time required).
  - Evaluate the effect of constructing GBS in smaller batches (5 or 10 maximum)

- Offshore installation:
  - Explore more effective installation scenarios (e.g. fast ballasting)
  - Investigation of higher workability for towing and installation to reduce delays and eventually installation costs.

- Investigate the end-of-life options and decommissioning strategy

THANK YOU FOR YOUR ATTENTION

TNO.NL/ECNPARTOFTNO