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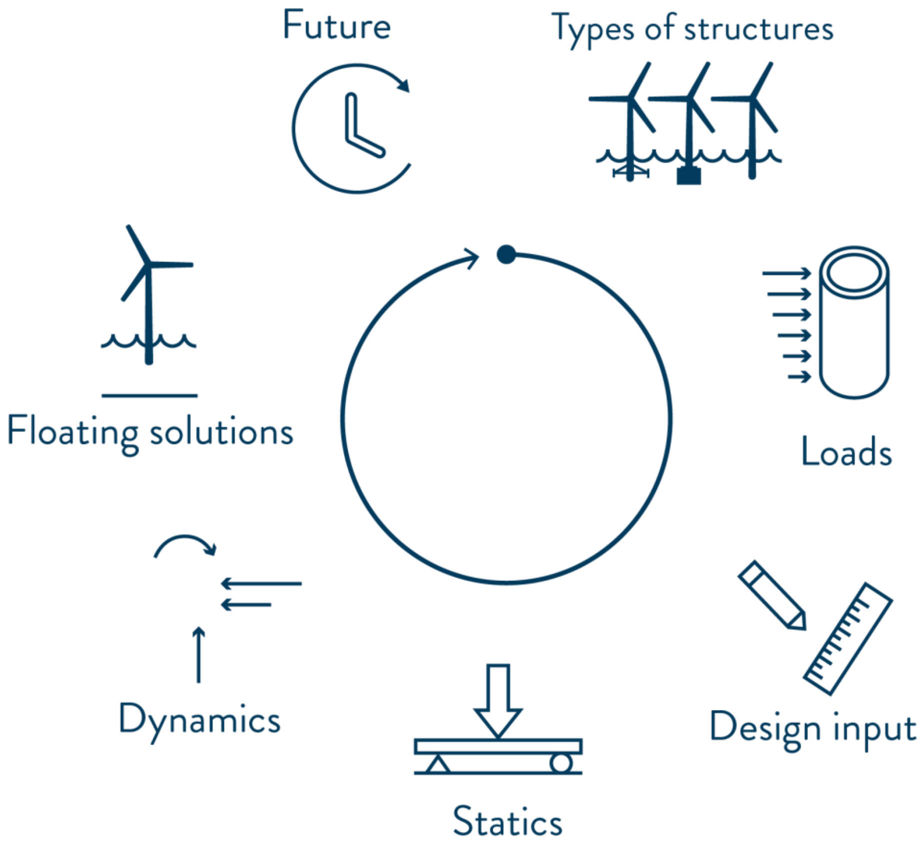
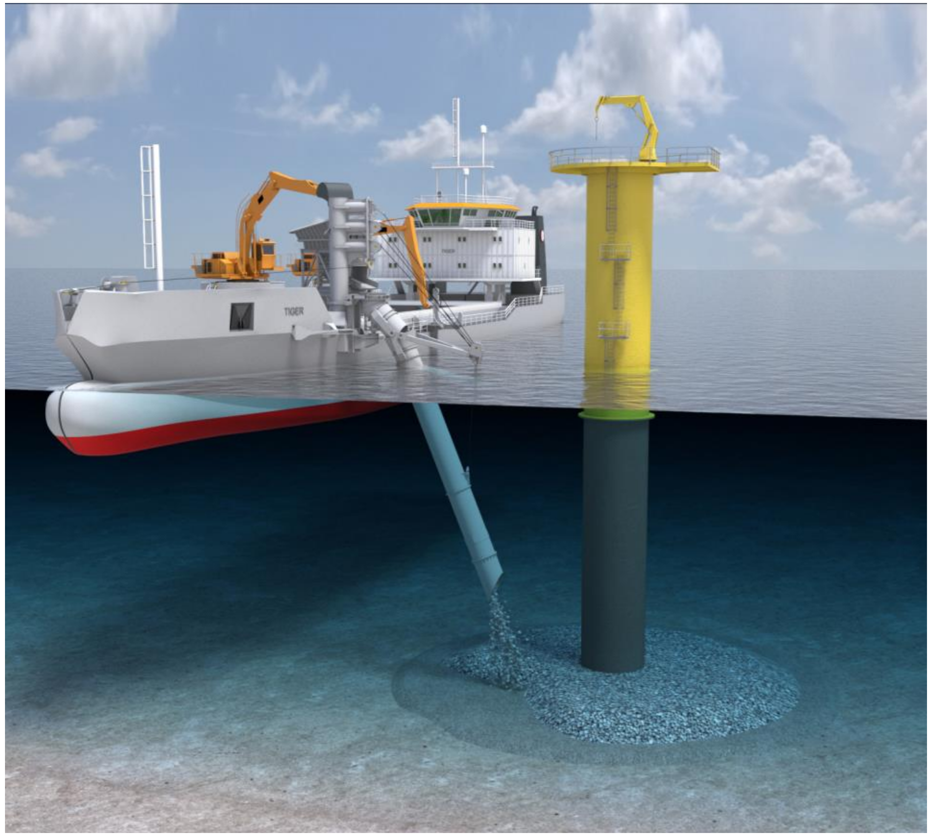
Floating structures

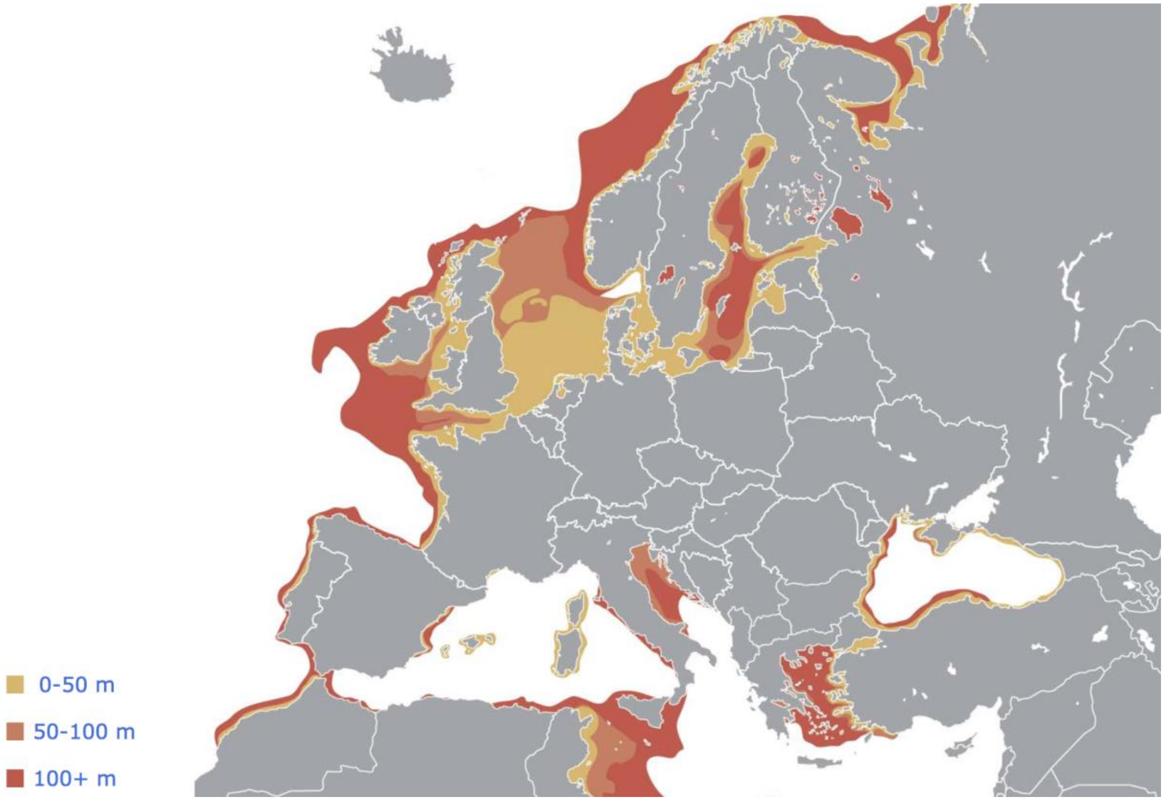


Current wind farms: bottom founded



Deeper waters

- Limited availability of shallow water
- Stronger winds
- New markets

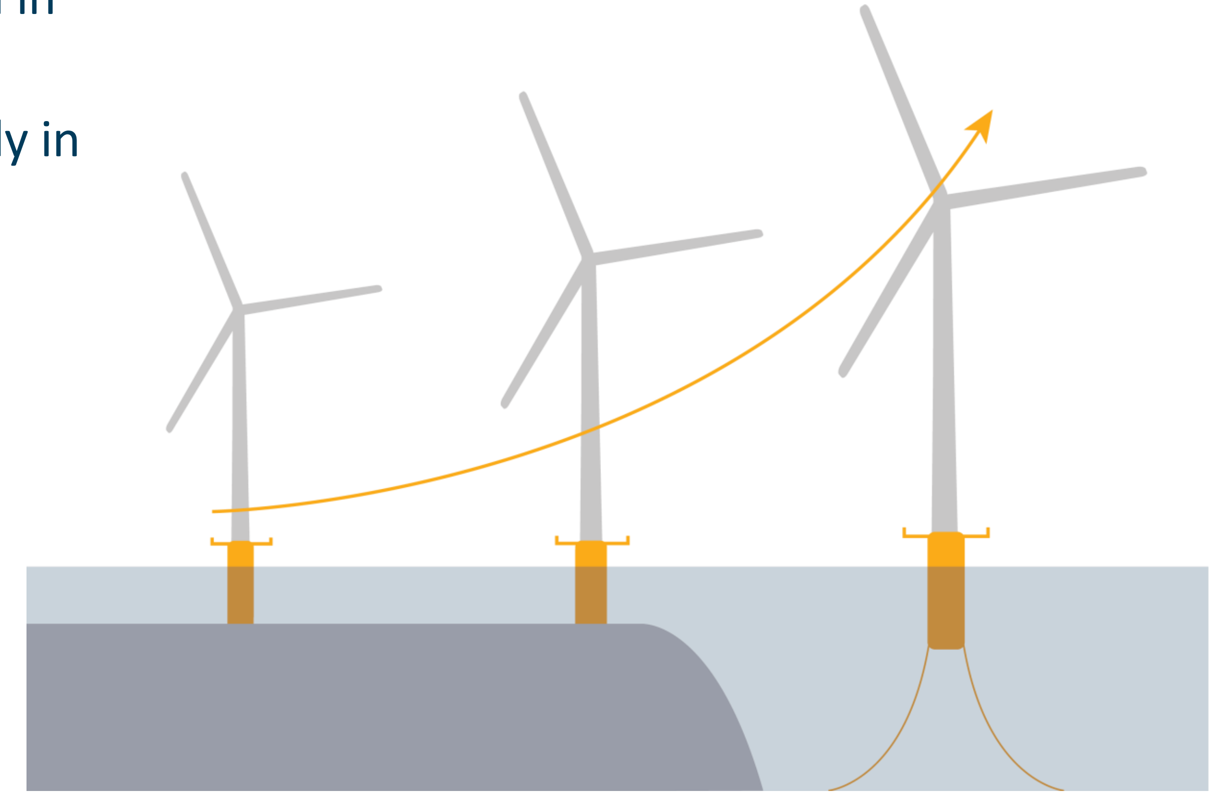


Acciona,

1-Tech, DNV

Larger turbines

- Very large turbines are expected in the future
- Monopiles increase exponentially in size
- Jackets are labour intensive



Floating wind

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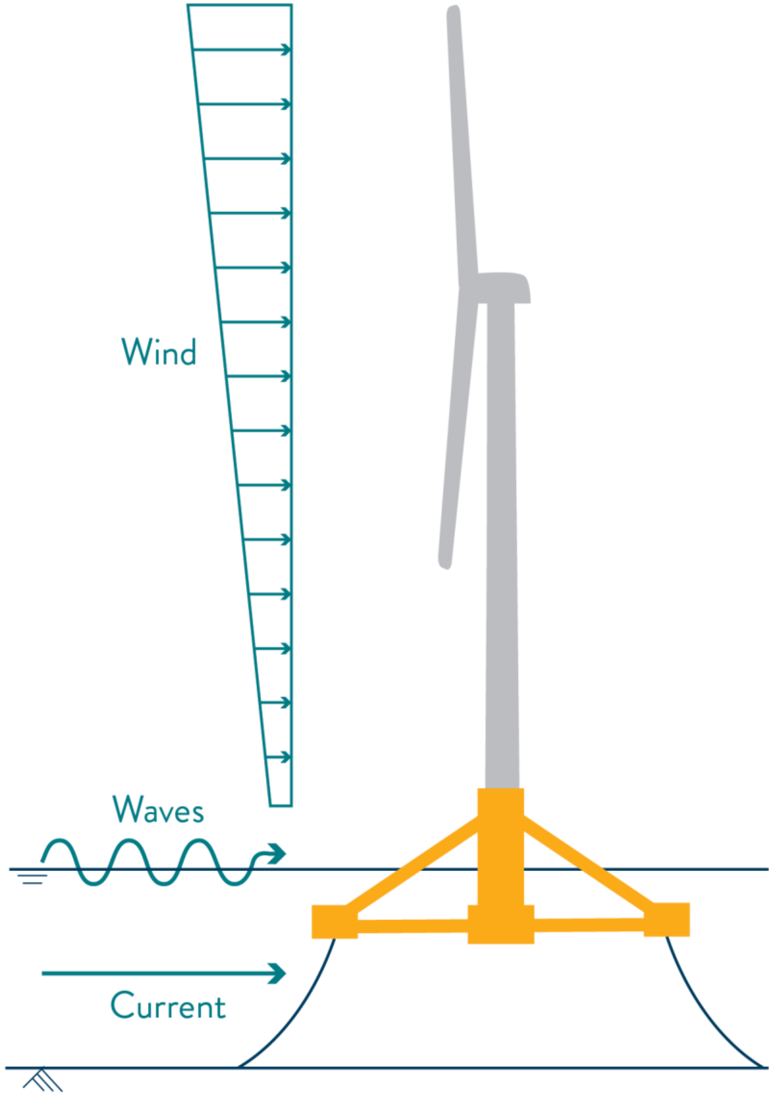
Floating wind

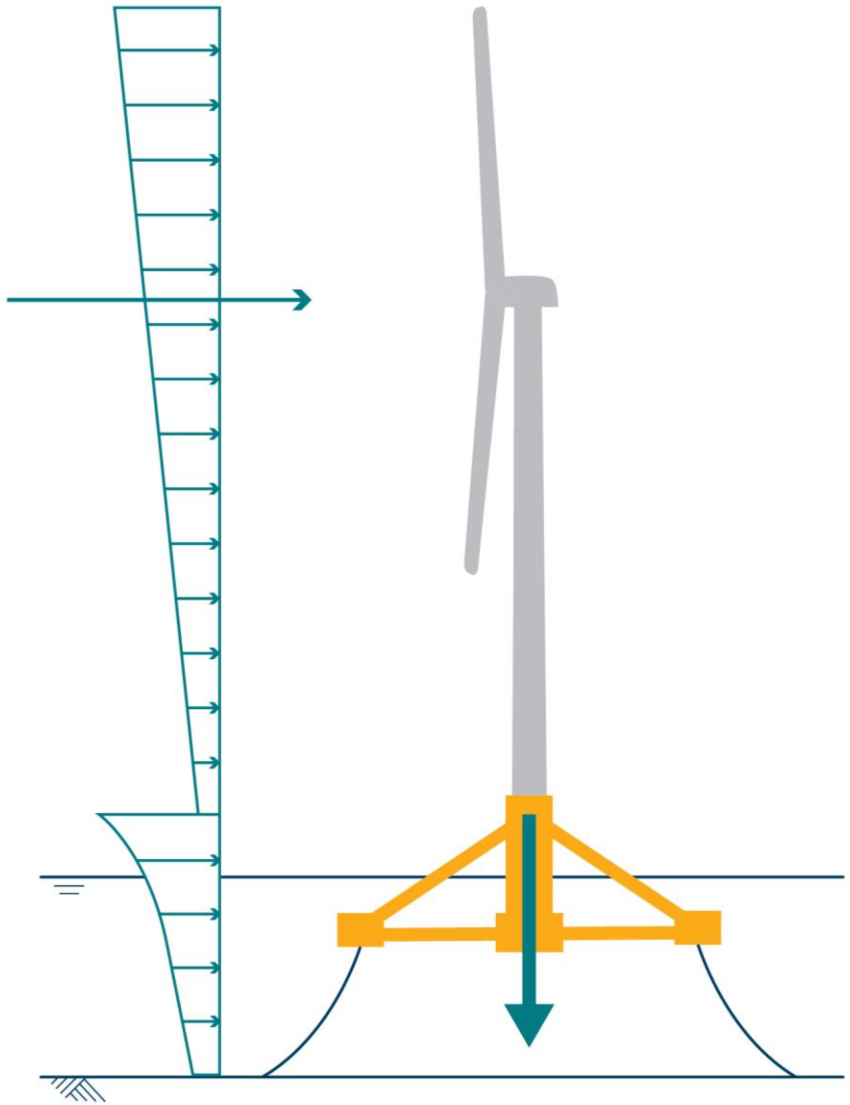
- Less dependent on water depth
- More beneficial for larger turbines
- Ease of installation
- Independence of soil conditions
- Standardized design
- Less noise pollution at installation

Loads



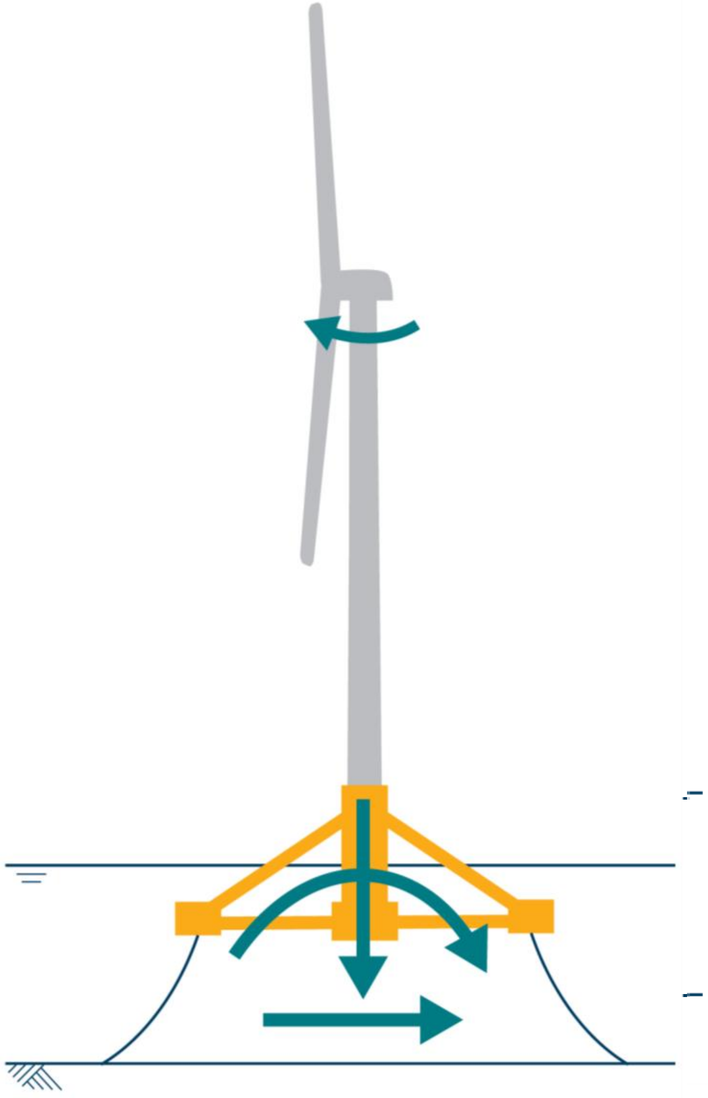
Type of loads

- Aerodynamic loads
- Permanent loads
- Hydrodynamic loads



Resulting forces

- Addition of all loads gives
  - Axial force
  - Overturning moment
  - Base shear

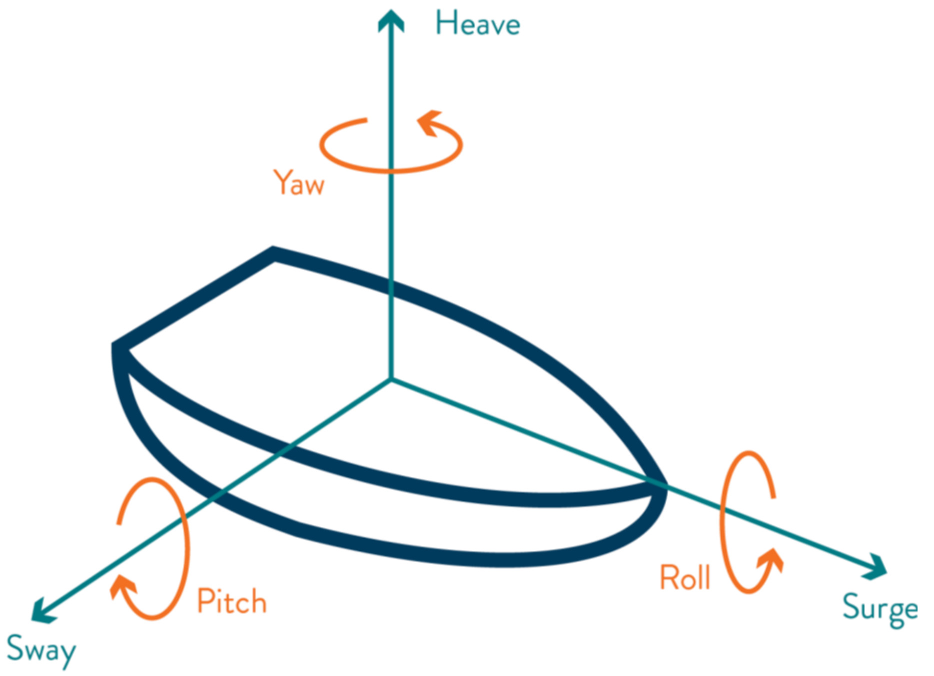


Design input for floating structures

- Mostly same as Bottom founded structures
- Motions
- Stability

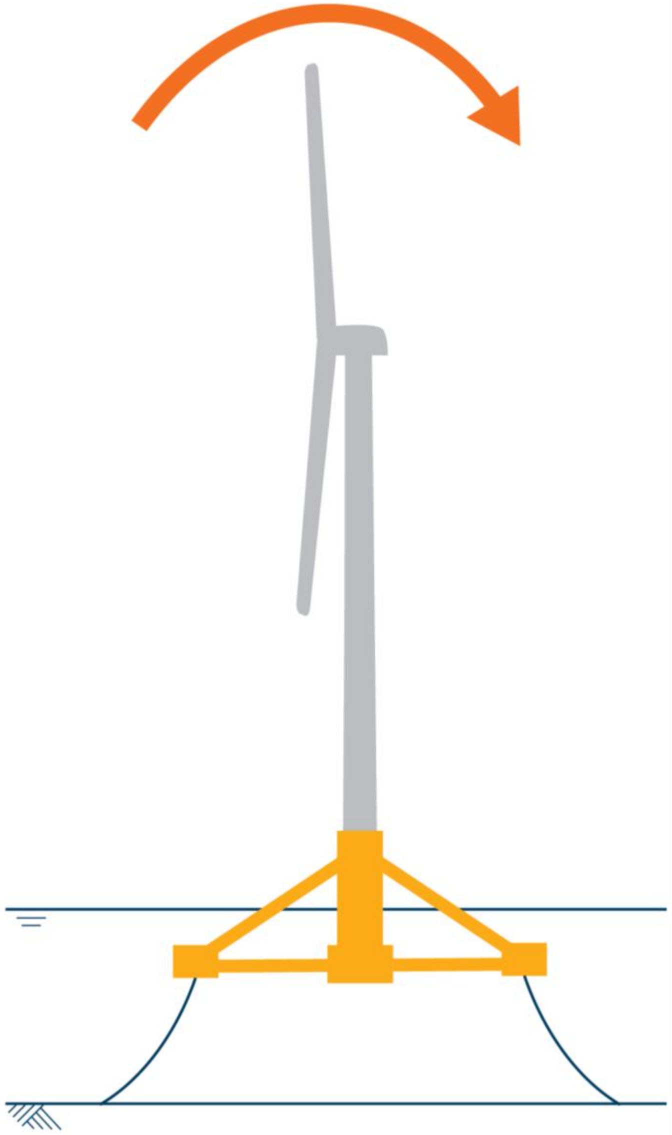
Motions floating structures

- Translational motions
- Rotational motions

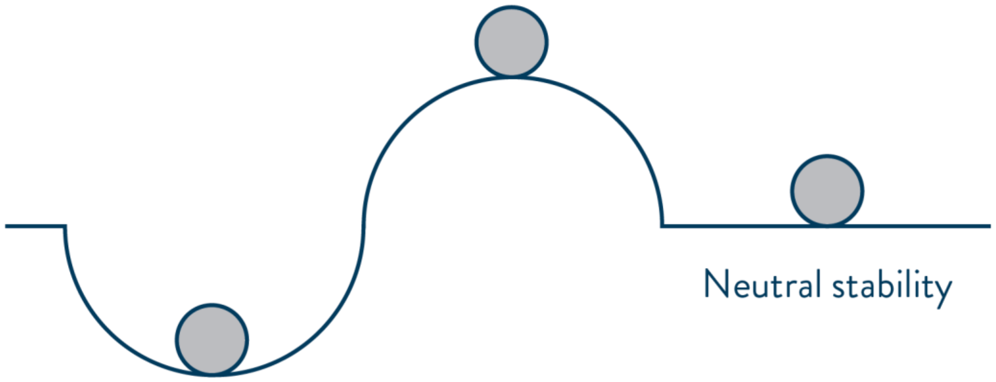


Motions wind turbine

- Turbines allow for smaller motions than ships
- Small rotations at base give large rotations at hub
- Collision of blades and tower

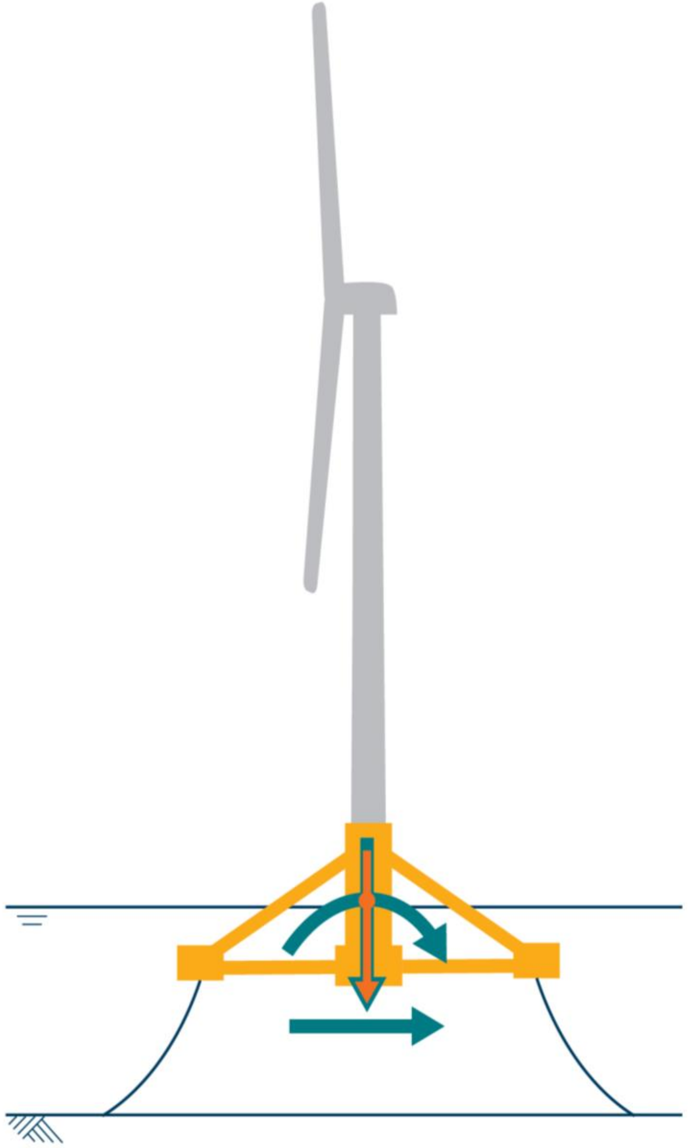


Stability



Axial force

- Permanent load gives axial force
- Compensated by buoyancy



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Why does a structure float?

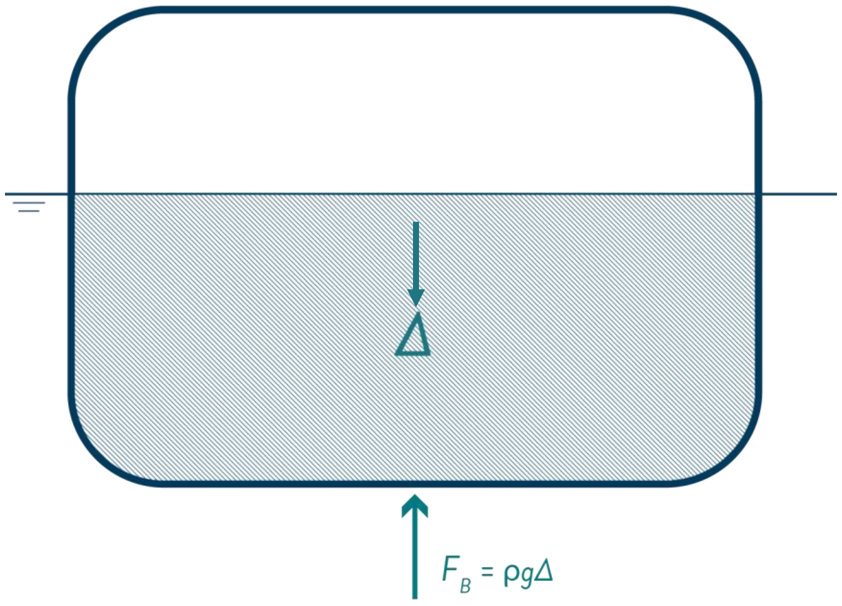
- Floating body:

Buoyancy = Weight of structure = Weight of displaced liquid

- $\Delta = \rho \cdot g \cdot \nabla$

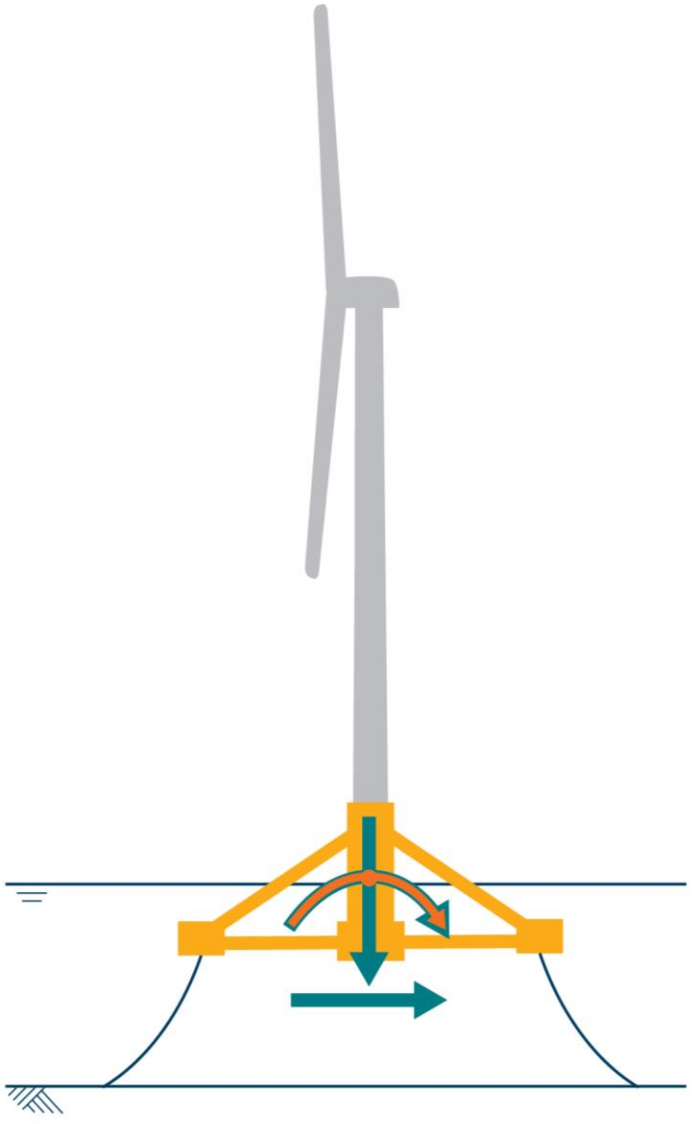
Δ = weight of displacement

∇ = volume of displacement



Overturning moment

- Aerodynamic and hydrodynamic loads give overturning moment
- Stable equilibrium of a structure can compensate for this moment



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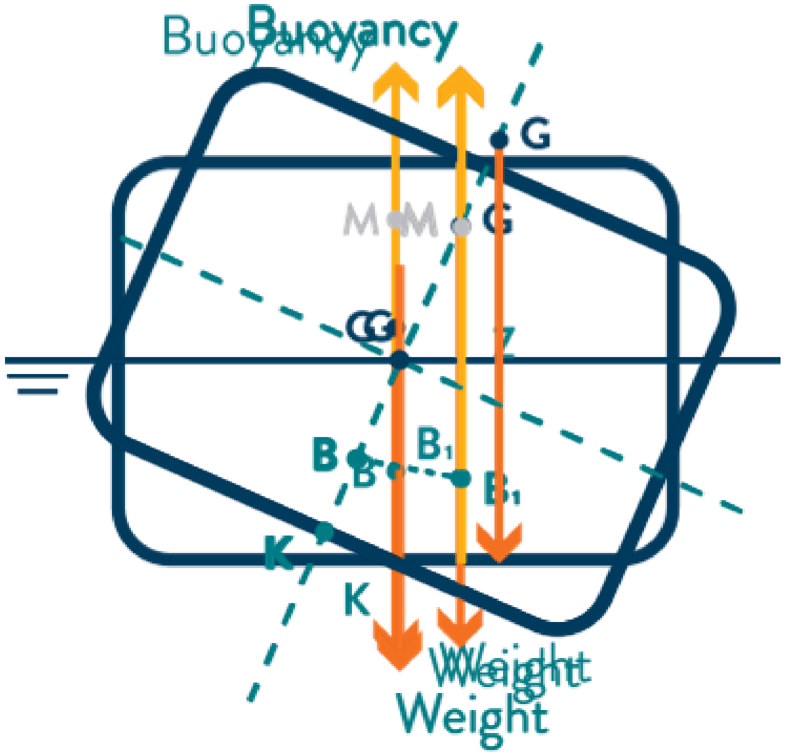
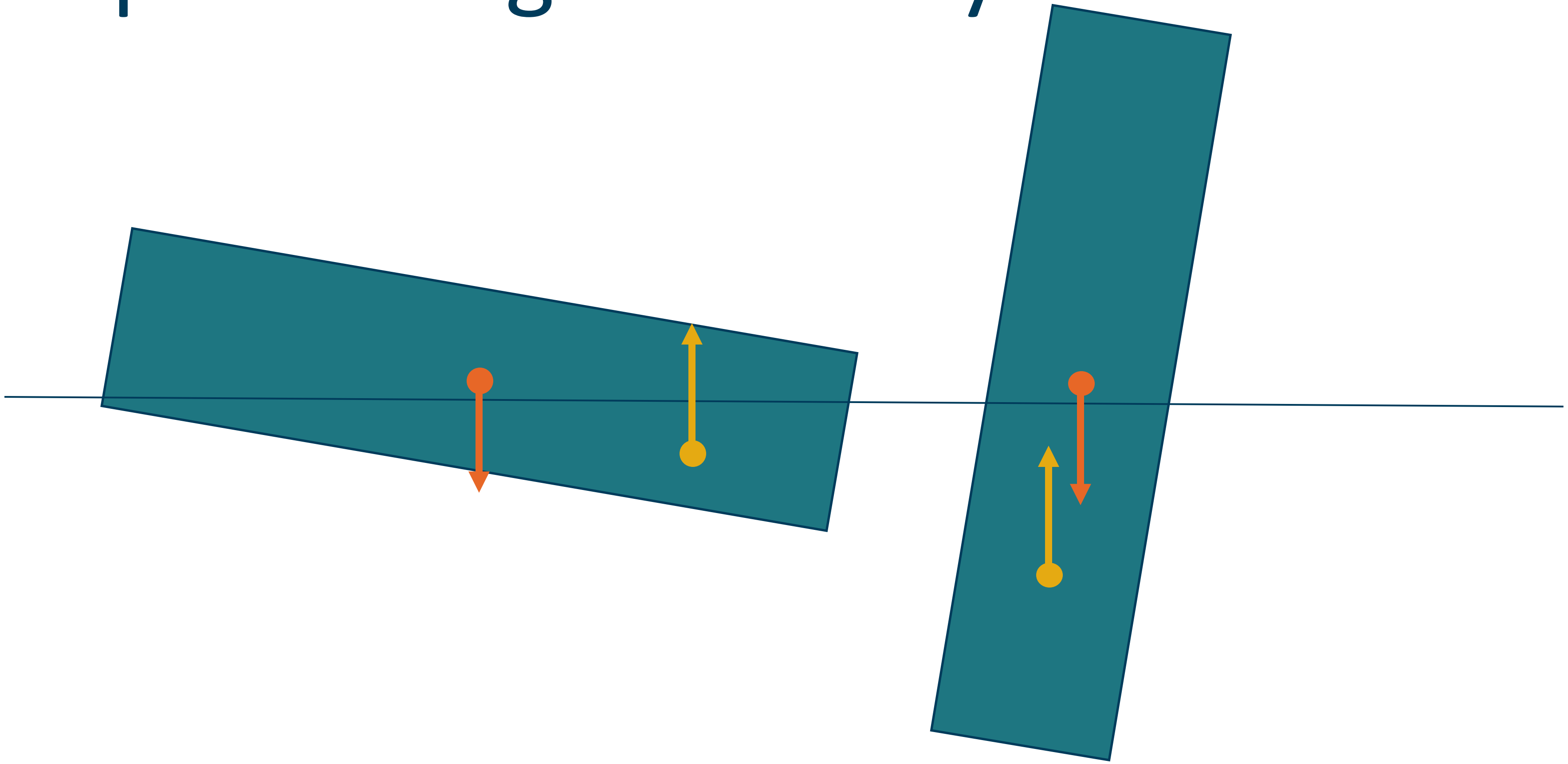
Floating stability

- GM = KB +BM – KG
- Stable: Buoyancy works as a restoring force → GM > 0
- Neutrally stable: Buoyancy and gravity work in line → GM = 0
- Unstable: Buoyancy works as a negative restoring force → GM < 0
- GM is most important design parameter

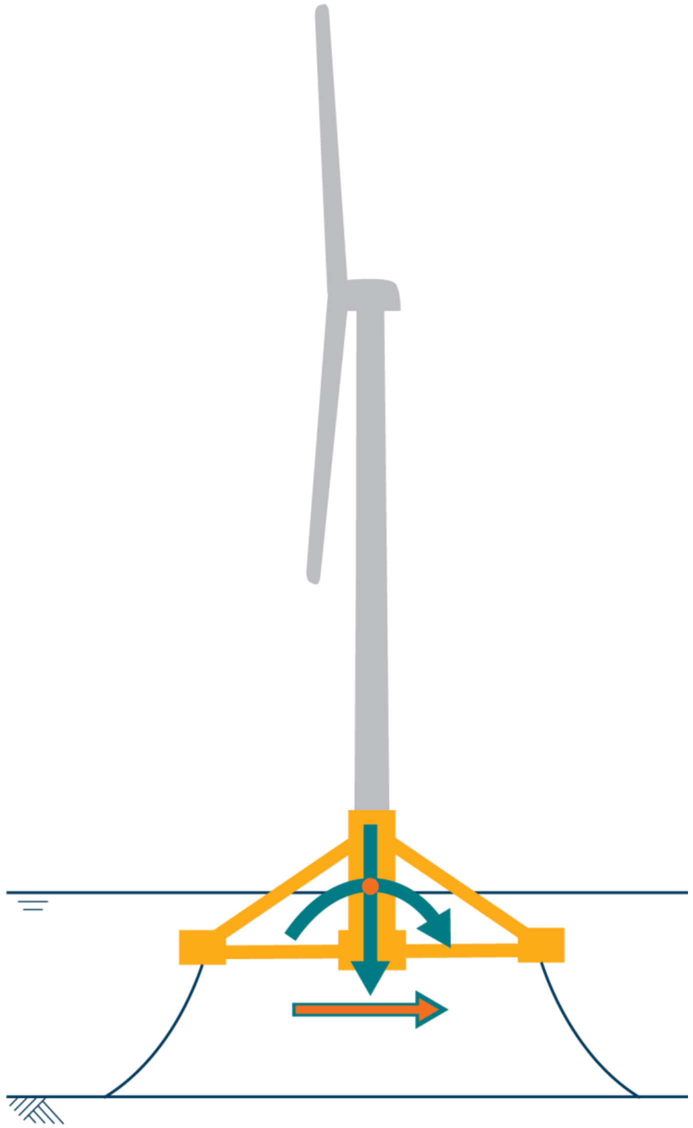


Shape or weight stability



Base shear

- Aerodynamic and hydrodynamic loads give base shear
- Anchoring ensures a restoring force



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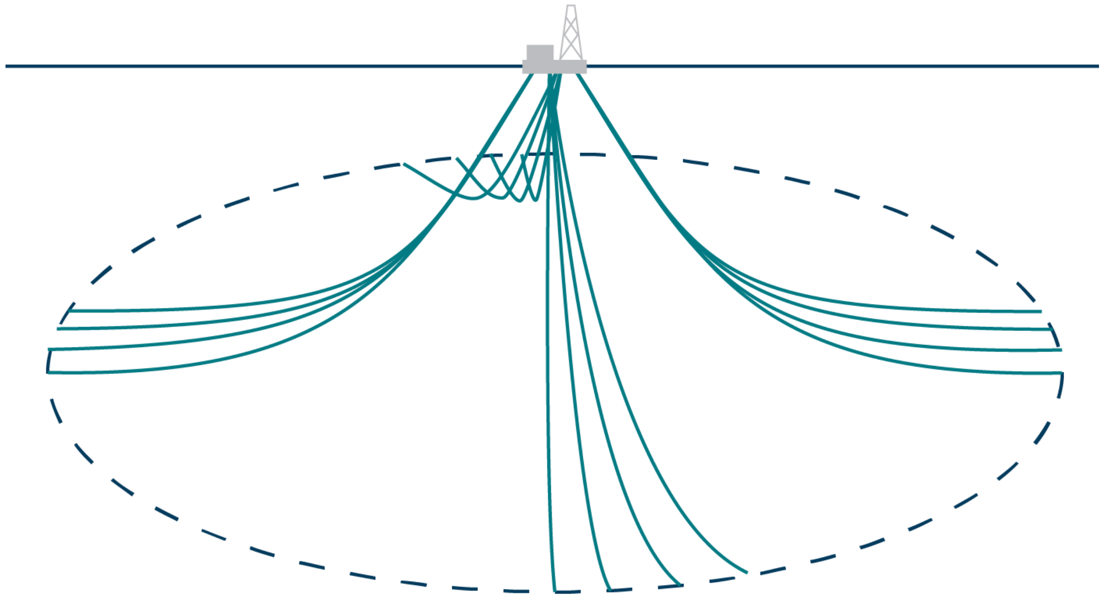
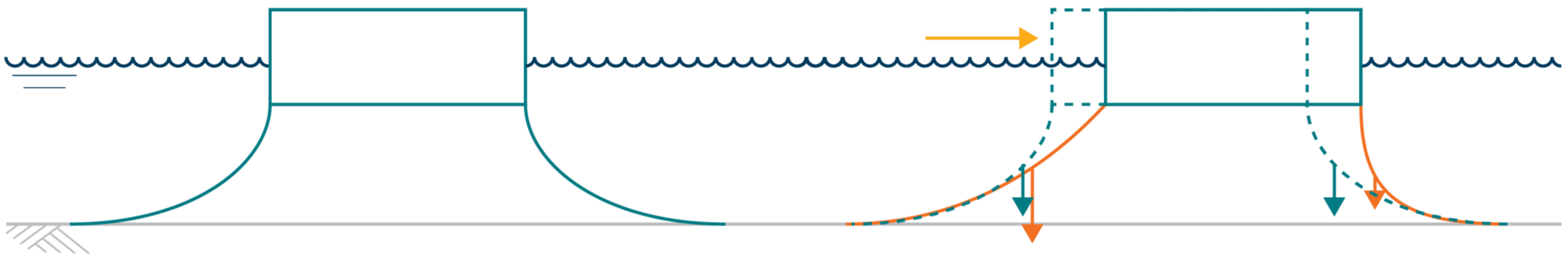
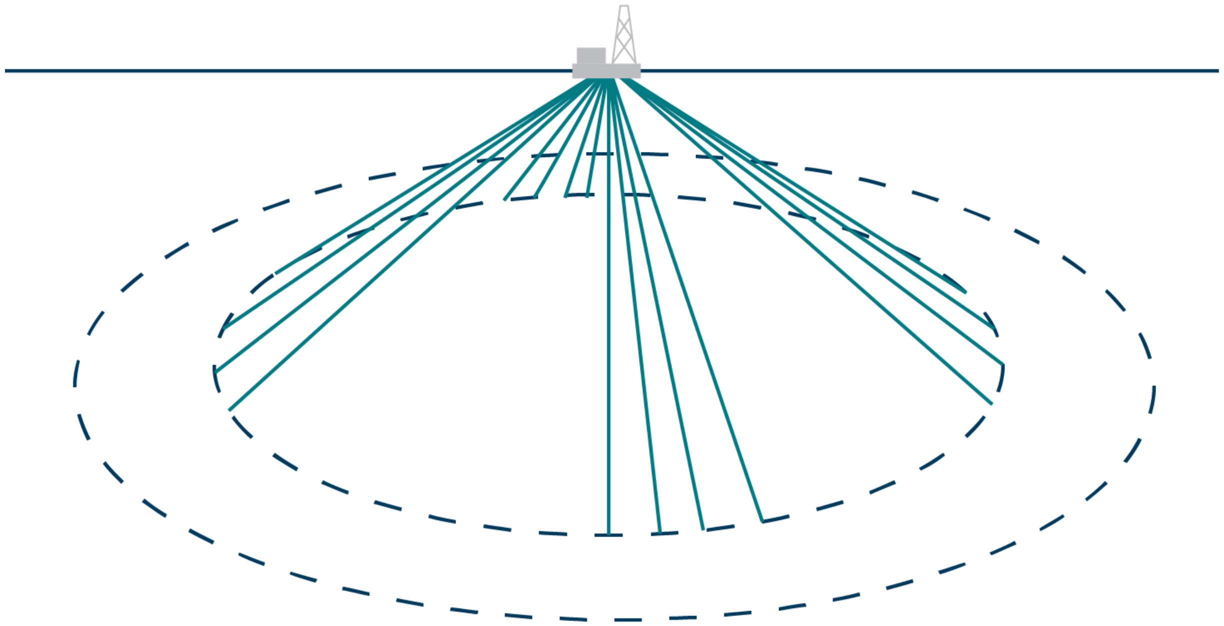
Catenary mooring



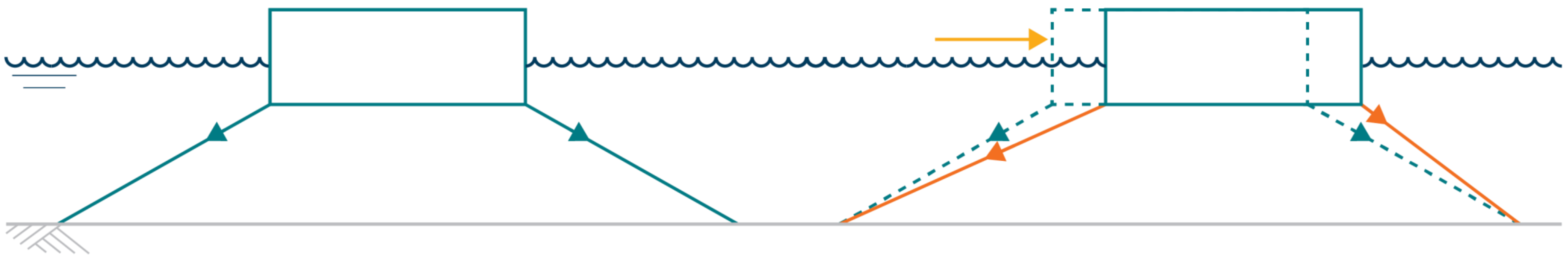
Restoring forces catenary mooring



Taut leg mooring



Restoring forces taut-leg mooring

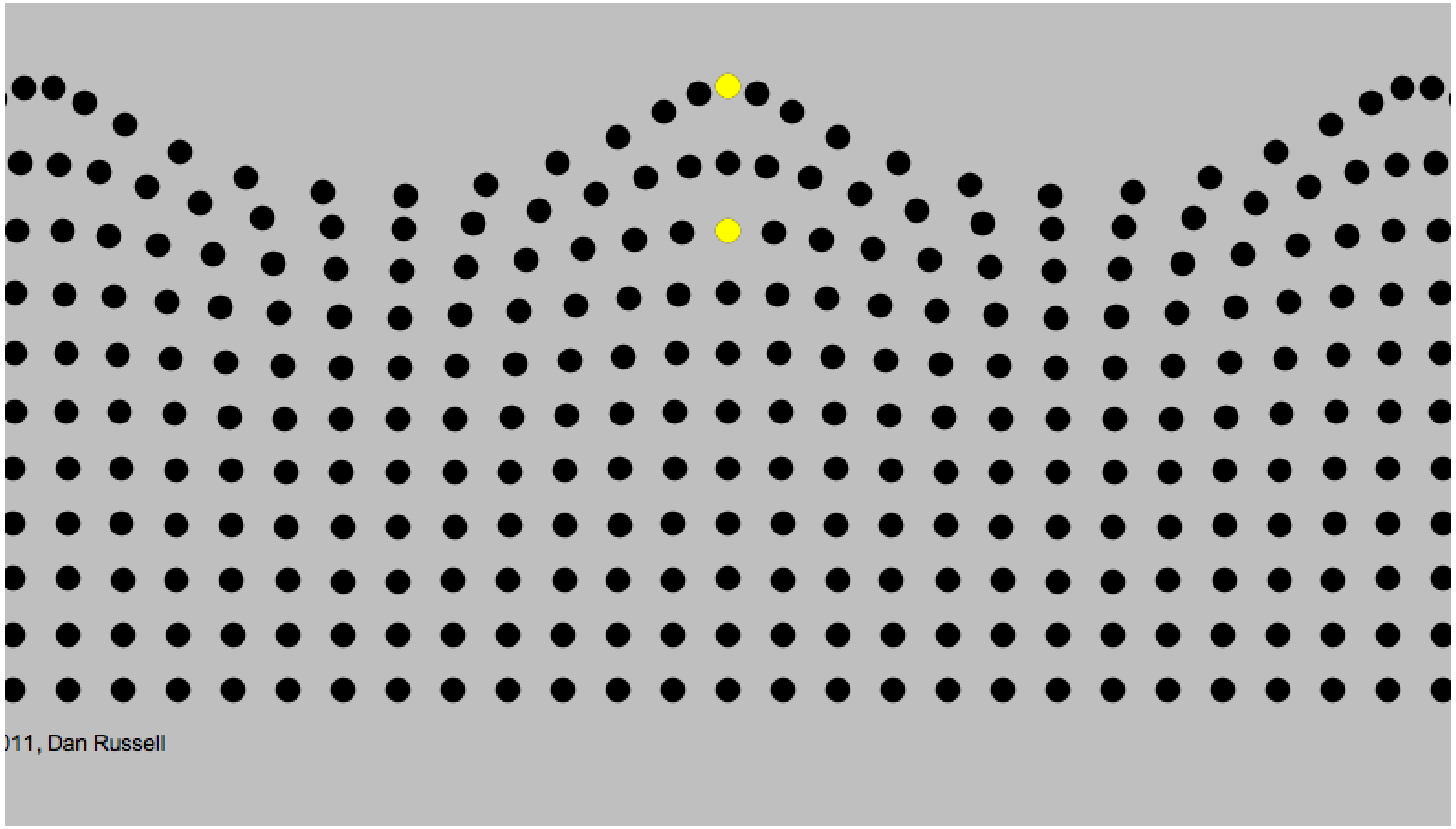


Dynamics

Hydrodynamics

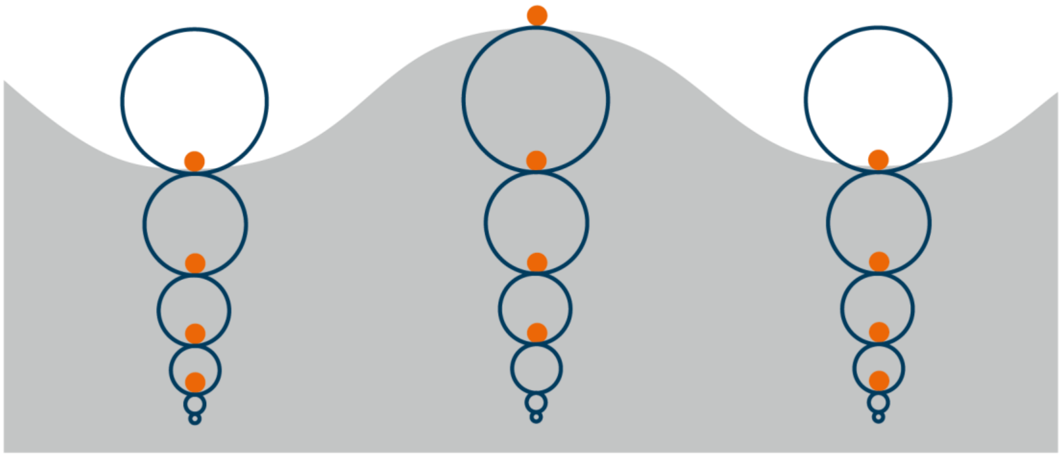
Aerodynamics

Wave loading



Dan Russell

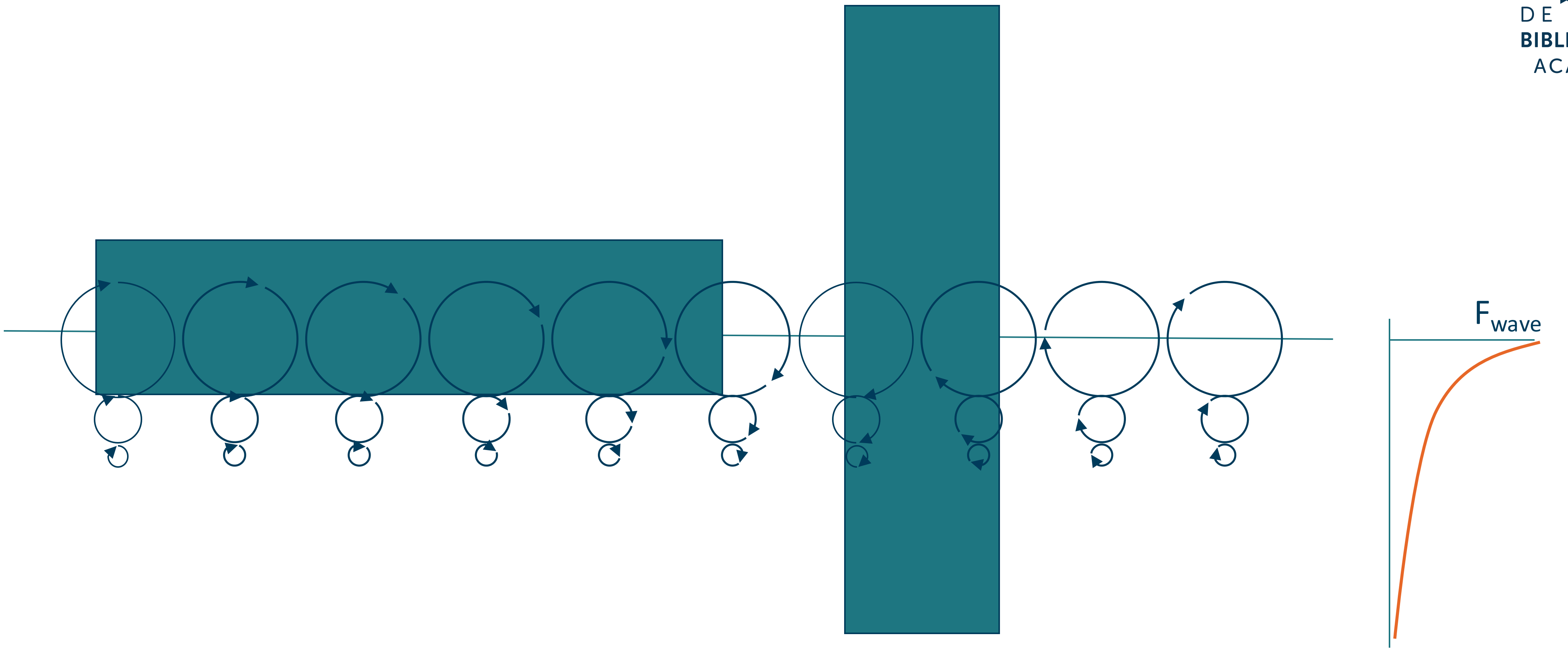
Linear wave theory



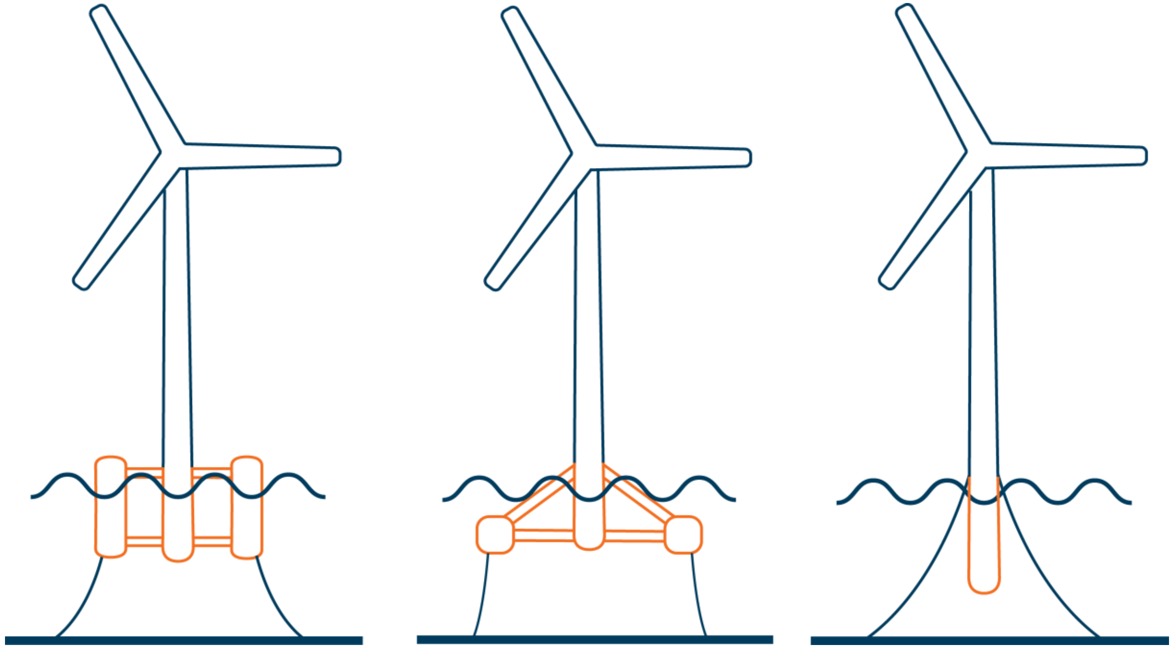
$$u_n(z,t) = \zeta_{a,n} \cdot \omega_n \cdot \frac{\cosh k_n(z+d)}{\sinh k_n d} \cdot \sin(\omega_n t + \varepsilon_n)$$

$$\dot{u}_n(z,t) = \zeta_{a,n} \cdot \omega_n^2 \cdot \frac{\cosh k_n(z+d)}{\sinh k_n d} \cdot \cos(\omega_n t + \varepsilon_n)$$

Broad vs Slender bodies

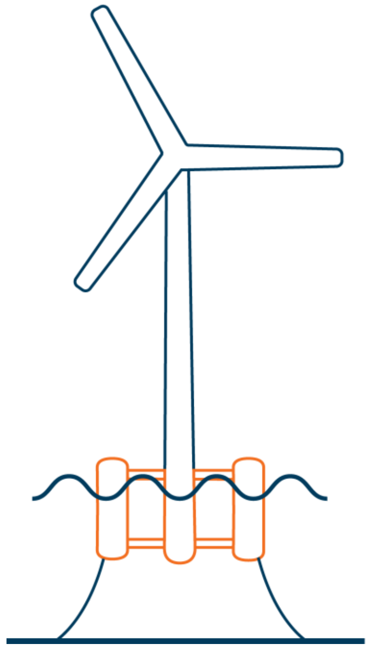


Floating solutions



Semi submersible

- Buoyancy from pontoons
- Spacing between pontoons provides stability
- Extra dampening possible using various techniques



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Semi submersible

- Pros:
  - Easy to transport
  - Onshore turbine assembly
  - Low draft
- Cons:
  - High structural cost
  - Complex steel structure

WindFloat

Current project: WindFloat

- 2MW prototype
- Currently commissioning of 25 MW farm
- Active ballasting in the columns
- Damping plates on the bottom of the columns

WindFloat


Vestas
WF1

Spar

- Deep draft design reduces wave loading
- Ballast in the lowest part of the structure provides stability

Spar

- Pros:
  - Simple design
  - Easy fabrication
- Cons:
  - Offshore turbine assembly
  - Large draft

Hywind

Current project: Hywind

- First floating windfarm realized!
- 5x6 MW
- Depths up to 800m possible
- Pitch control actively stabilizes the system

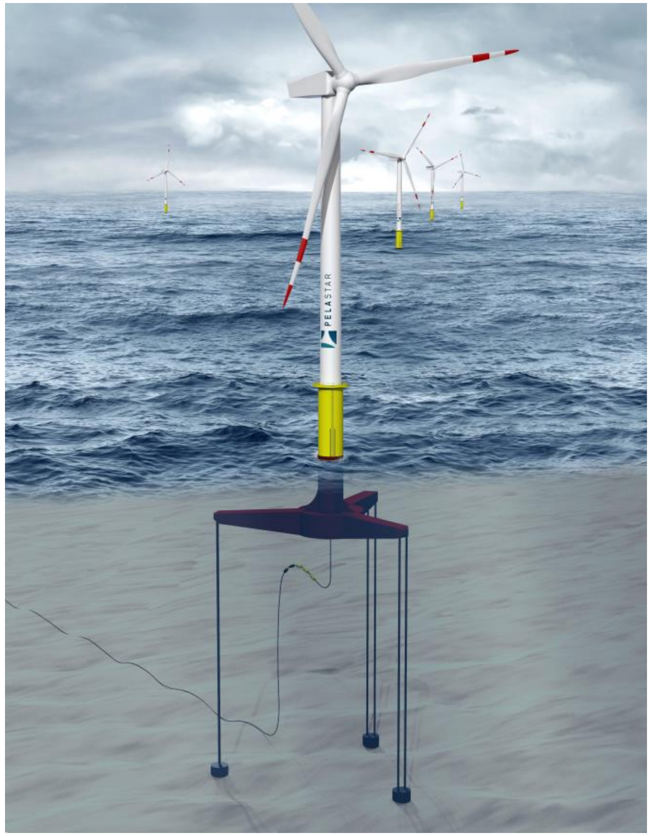
Hywind

Tension Leg Platform (TLP)

- Large buoyancy force provides stability
- Tethers (lines) with high axial stiffness
- Virtually no vertical motions

Tension Leg Platform (TLP)

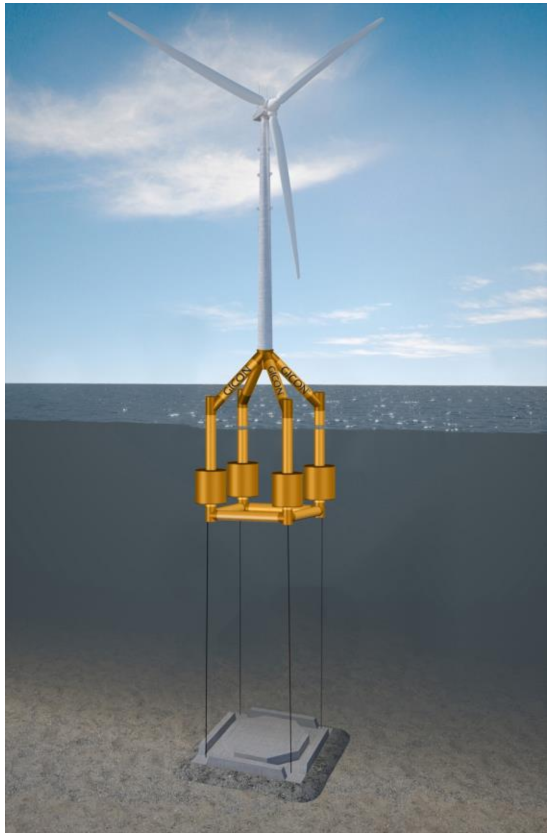
- Pros:
  - Onshore turbine assembly
  - Low structural mass
- Cons:
  - Challenging transport and installation
  - High loads on mooring and anchoring system



GICON

Current project: GICON

- 4 linked columns anchored to seabed
- New design for depths up to 350m



GICON

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Benefits of floating wind

- Beneficial for larger turbines and larger water depth
- Linear increase of cost with depth instead exponential
- Same design for larger turbines
- Technically feasible

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Main barriers

- Platform size and weight
- Platform production rate
- Installation procedures
- High cost of early demonstration
- Long-term uncertainty blocks investments


SAIPEM 7000

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