

Oil & Gas Industry Transition to Renewable Energies & Floating Offshore Wind

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Transition to Renewables

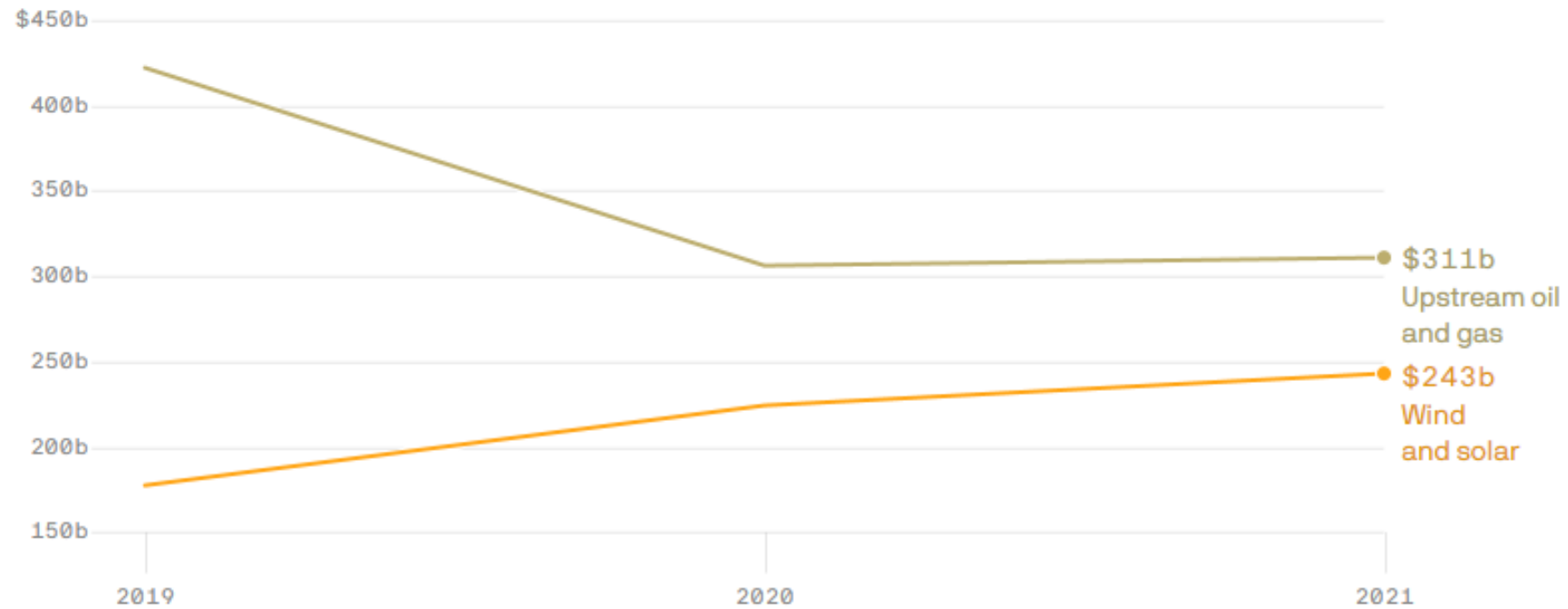
Integrated Oil Companies (IOC) becoming International Energy Companies (IEC)

- Shell – Net zero emissions energy business by 2050
- Total – Net Zero across worldwide operations by 2050 or sooner (scope 1+2) and for Europe (scope 1+2+3)
- Equinor – Net Zero Emissions by 2050 (Scope 1+2+3)
- ENI – Net Zero by 2050 (Scope 1+2+3)
- bp – Net-zero by 2050 or sooner and help the world get to net zero
 - Aim to reduce O&G production by ~40% by 2030 & increase low carbon investment 10-fold
 - Aim to develop 50 GW growth in renewables capacity by 2030 across solar and wind with expected 20 GW growth in Offshore Wind
- Others following suite
- Cut spending on oil & gas projects with emphasis on highest value, lowest emissions and gas

Example of low carbon growth – CAPEX Comparison

Capital spending for oil and gas and renewables projects

2019-2021



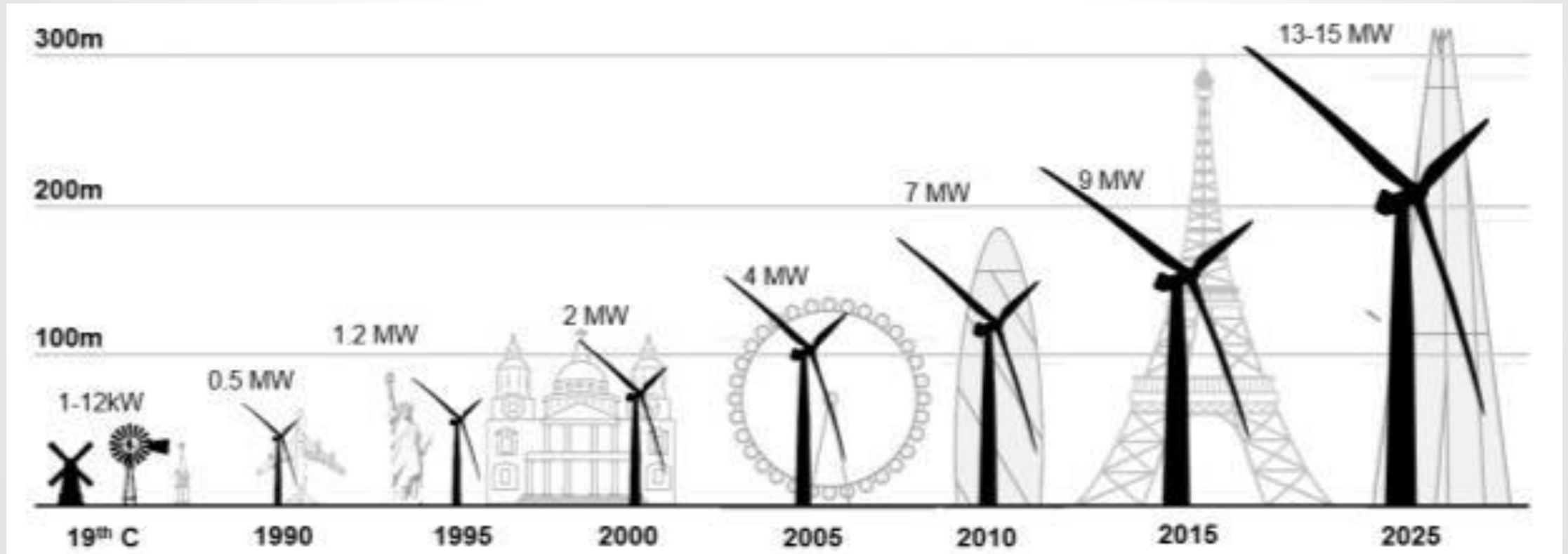
Variety of sources for low carbon energy – wind, solar, hydro, nuclear, etc.

- Clear drive towards electrification
- Focus today on offshore wind and in particular floating wind



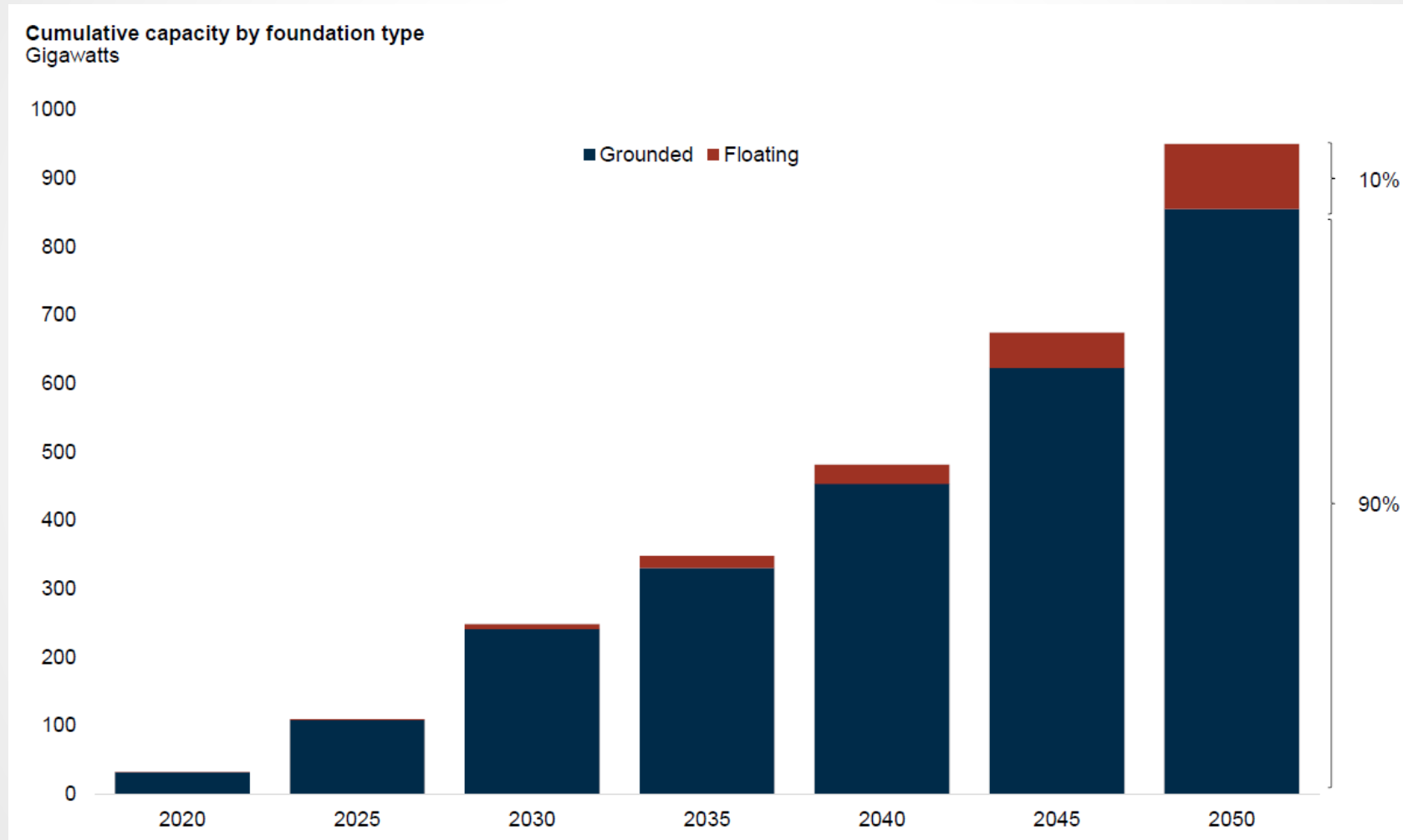
Offshore Wind – Trends

Turbines will continue to get bigger but is there a limit?
Current largest available Vestas V236-15.0 MW™



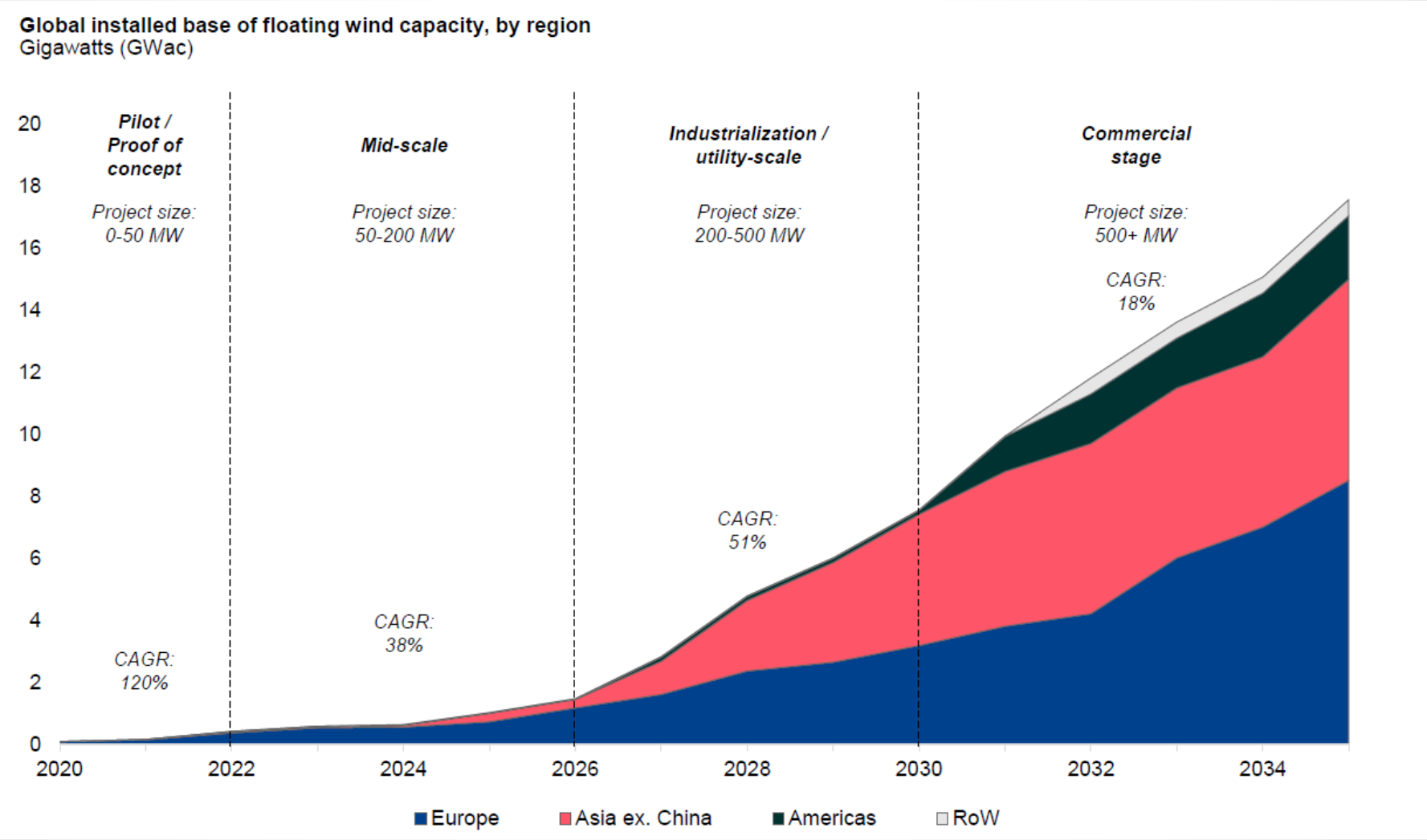
Offshore Wind – Trends

Rapid growth over the next few decades



Offshore Wind – Trends

Floating Offshore Wind Growth looks to be even more rapid



Offshore Wind – Trends

Offshore wind locations based on wind speed

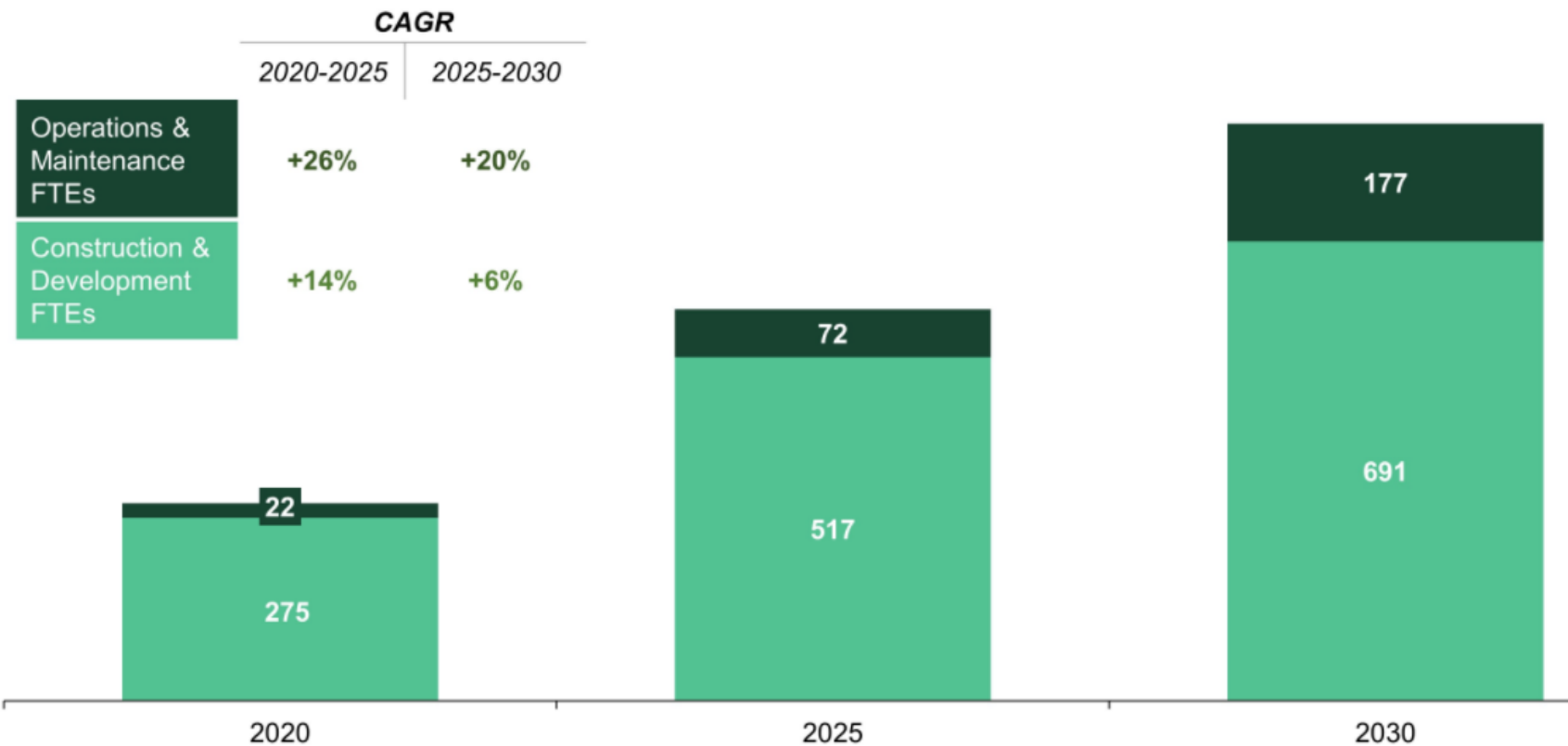


Offshore Wind – Trends

It will require a lot of people to design, build & operate these offshore wind farms



Outlook for employment demand in the offshore wind sector
Thousand FTE* roles



*FTEs stands for full time equivalent workers

Floating Offshore Wind – Another Way of Working Offshore



Topics:

- Role of the metocean engineer
- Field layout optimization
- Offtake
- Preferred hull form
- Floater design
- Construction
- Supply chain
- Offshore installation and servicing equipment

Floating Offshore Wind – Another Way of Working Offshore



Topics (cont.):

- Site conditions
- Standards
- Lower CAPEX and OPEX
- Levelized Cost of Energy (LCOE)
- Operations
- Decommissioning

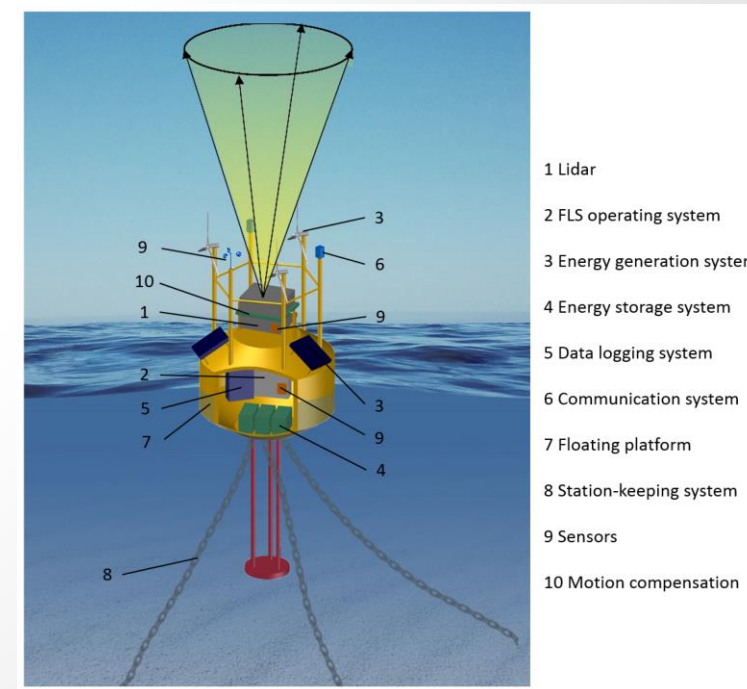
Floating Offshore Wind – Topics



- Metocean engineers are the reservoir engineers of wind
 - Traditional role - collecting data from site and using site data, hindcasting and climate models to develop site metocean design criteria will remain
 - New role – wind resource potential for annual expected energy yield
 - Site monitoring will require FLiDAR versus anemometers



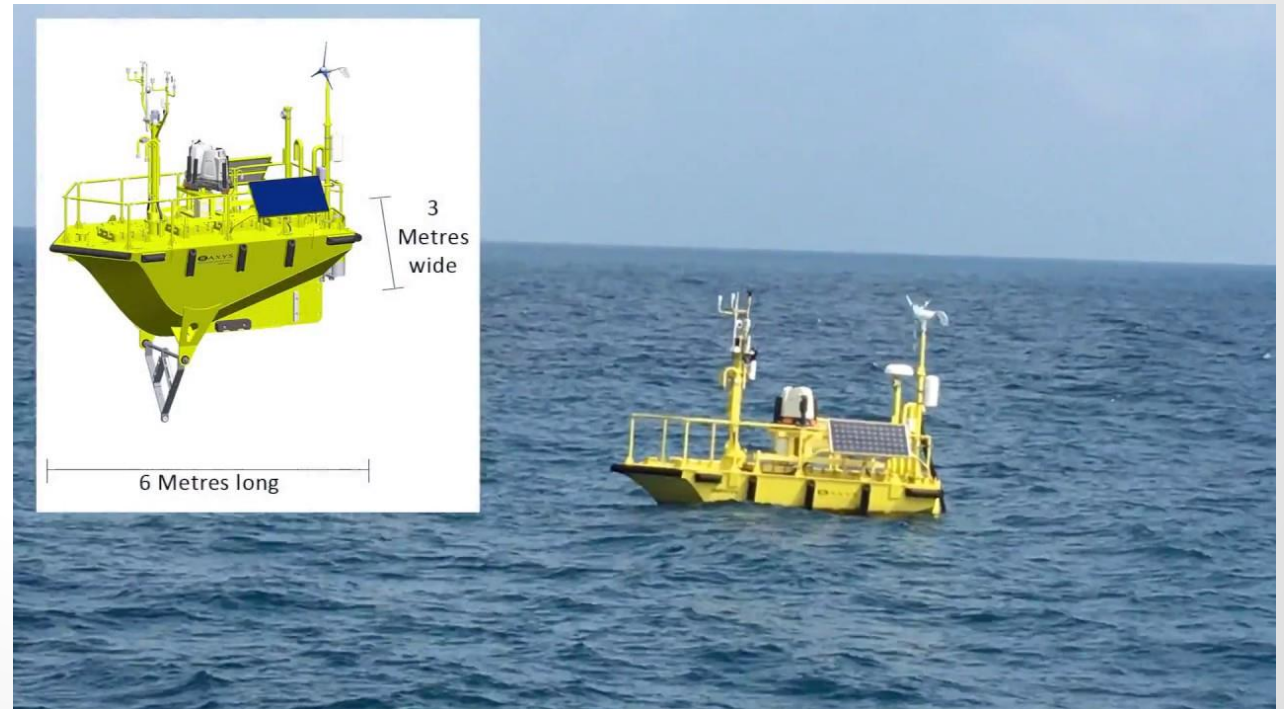
Source: Fugro
FLiDAR – Floating light detection and ranging



Floating Offshore Wind – Topics



- Metocean Engineers are the reservoir engineers of wind
 - Requirements to demonstrate bankable wind – minimum 2 FLiDARs at site for 12 months
 - FLiDARs calibrated next to recognized and vetted coastal metocean tower
 - Important to get right instruments in right locations and ensure providing quality data



Source: AXYS

Offshore Wind – Topics



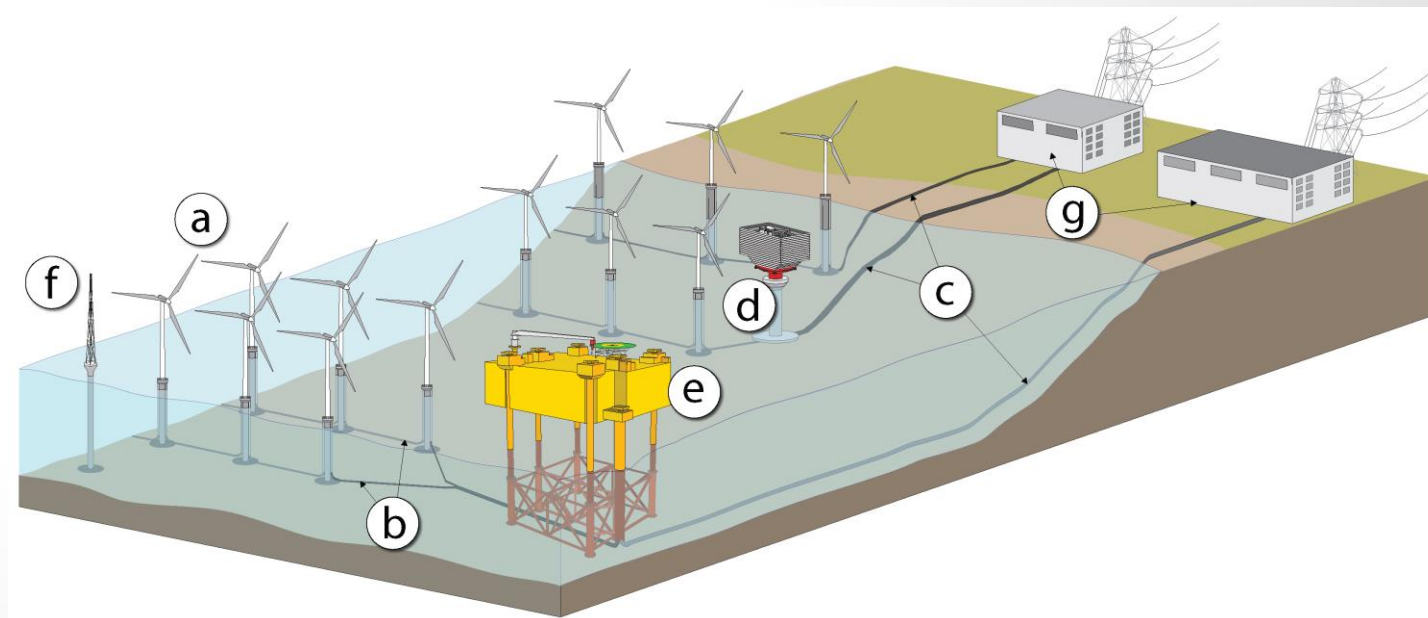
- Field layout optimization
 - Important aspect to get the lowest Levelized Cost of Energy (LCOE)
 - Wind farm array layout
 - Wind flow modeling
 - Wake turbulence



Offshore Wind – Topics

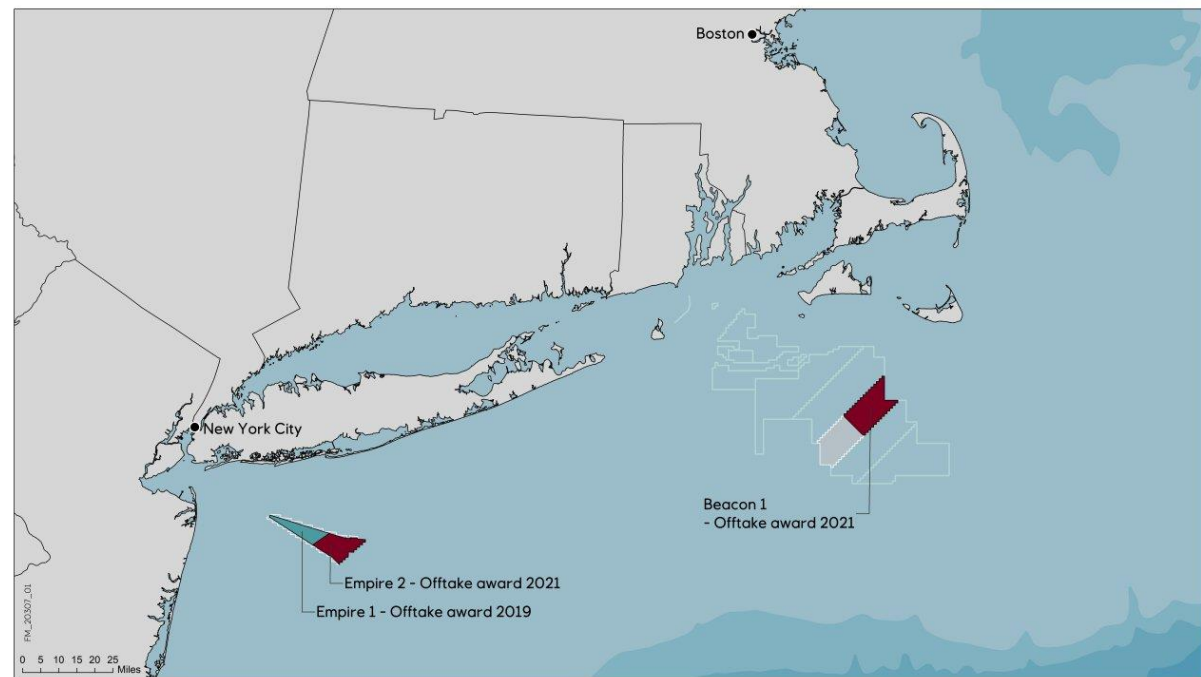


- Field layout
 - Use of Computational Fluid Dynamics
 - Turbine spacing of 7 x blade diameter for onshore may not work for offshore
 - With optimized layout, sharing of mooring anchors may be possible
 - Offshore substation location
 - Cable connections



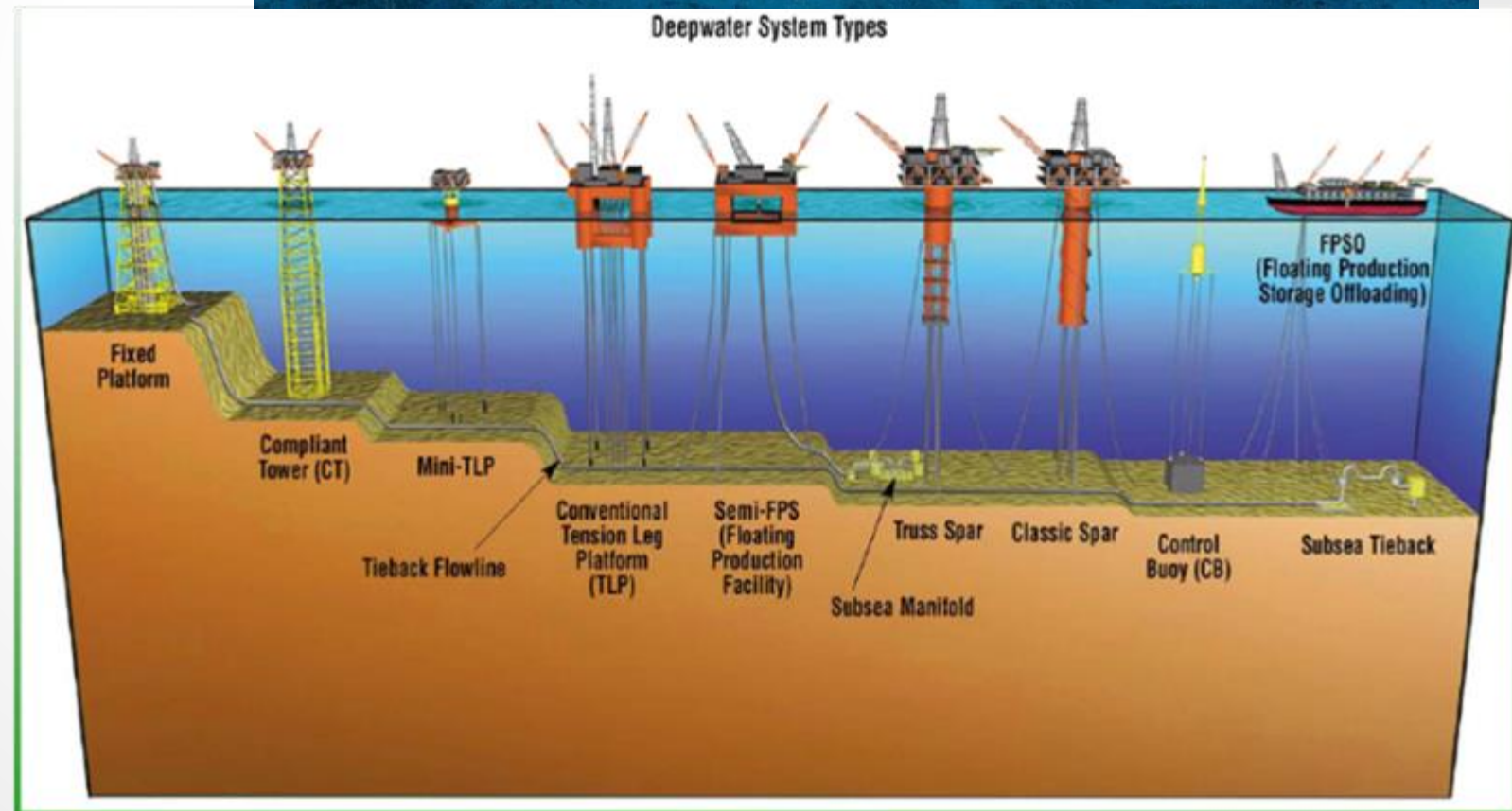
Offshore Wind – Topics

- Offtake
 - Not at all like O&G
 - Distance to existing grid tie-in point
 - Can impact value of lease
 - Power Purchase Agreements
 - Government subsidies may be involved
 - Non-performance



Floating Offshore Wind – Topics

- Preferred hull form?
- Will we need the 4 work horses like we needed for O&G?
- Vendor solutions



Floating Offshore Wind – Topics

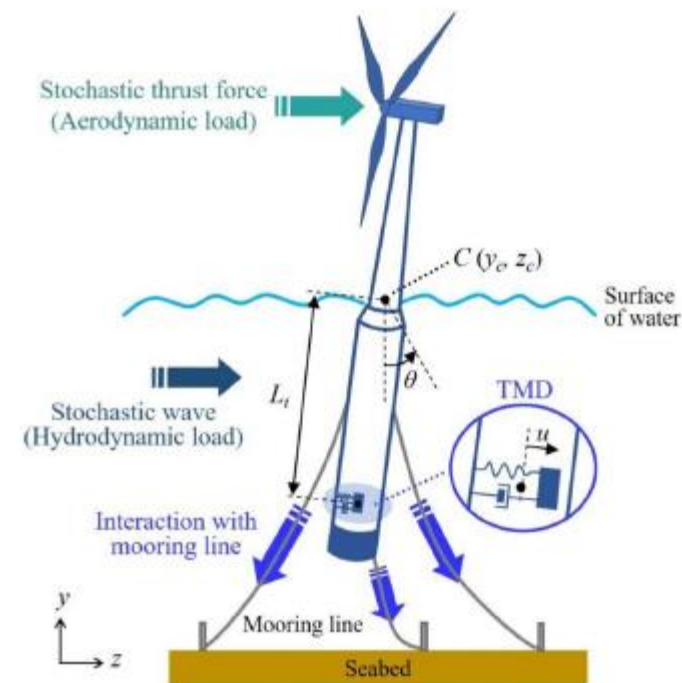
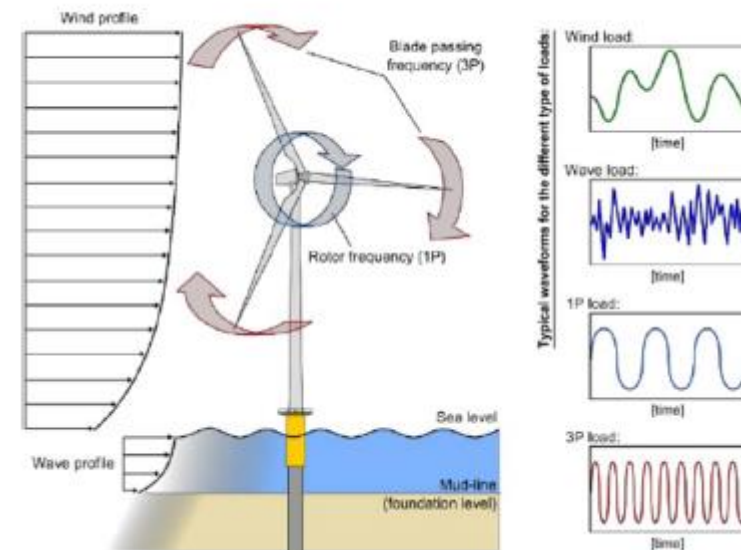


- Floater Design
 - Water depth for floating offshore wind is $\sim > 70$ m
 - Fixed bottom steel weight becomes more expensive
 - Limits of jack-ups to install wind turbine
 - Installed cost of floating offshore wind coming down
 - Size and height limits on turbine?



Floating Offshore Wind – Topics

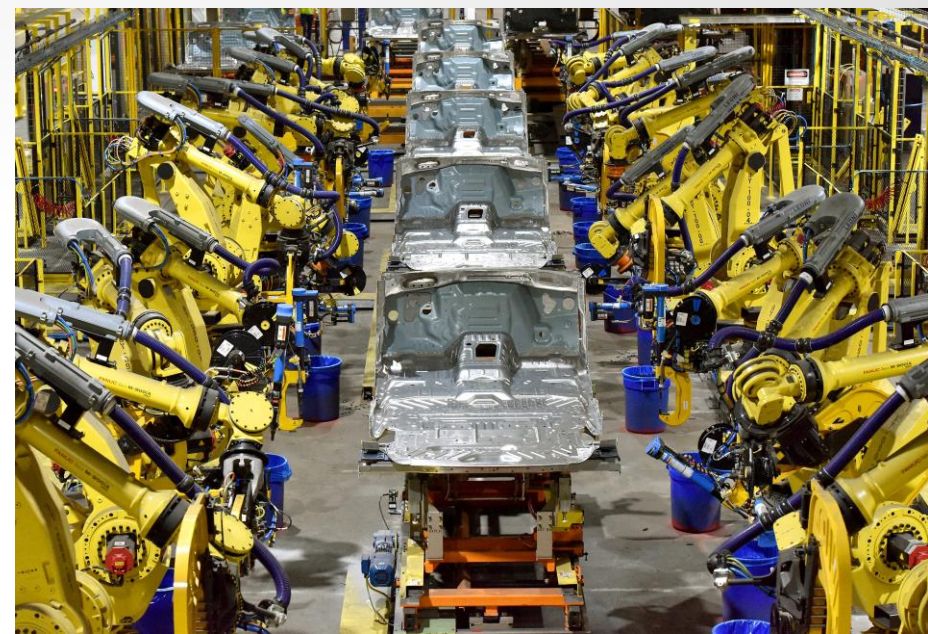
- Floater design
 - Global performance using coupled analysis will still be required
 - But topside interaction will be different
 - Software developed to analyze the problem
 - Mooring system will not have same level of redundancy
 - Active ballasting or other means to counteract turbine loads?
 - Best hull form for turbine design and energy yield?
 - Can we harness other sources of energy from hull real estate?



Offshore Wind – Topics

Construction

- Design one – build many
 - Will not be the bespoke design that we have used for oil and gas
 - Assembly line process (1 to several /week)
 - Over a field development and even multiple field developments with minor changes in water depth and metocean conditions, same hull and mooring will be used
 - Understand changes from standard design where it is cost effective to keep standard vs. redesigning



Floating Offshore Wind – Topics

Supply Chain

- Some similar supply chains, some new ones and more to enter
 - Engineering
 - Turbine and controls
 - Foundation
 - Cables
 - Transportation
 - Installation
 - Operations support
 - Type of contracting to be used



	Detail Design	Fabricate	Transport	Integrate	Commiss	Install
Hull	A	A	G	I	J	K
Process	B	A	H	I	I	K
Drilling	C	E	H	I	I	K
Mooring	D	F	F	X	X	K

Floating Offshore Wind – Topics

Installation



- Different use of offshore installation and servicing equipment
 - Started with the O&G offshore installation vessel
 - Dedicated fleet being built
 - Novel methods and equipment
 - Can it keep pace with growing industry?
 - Keeping pace with growing turbine?
 - Favor floating wind?



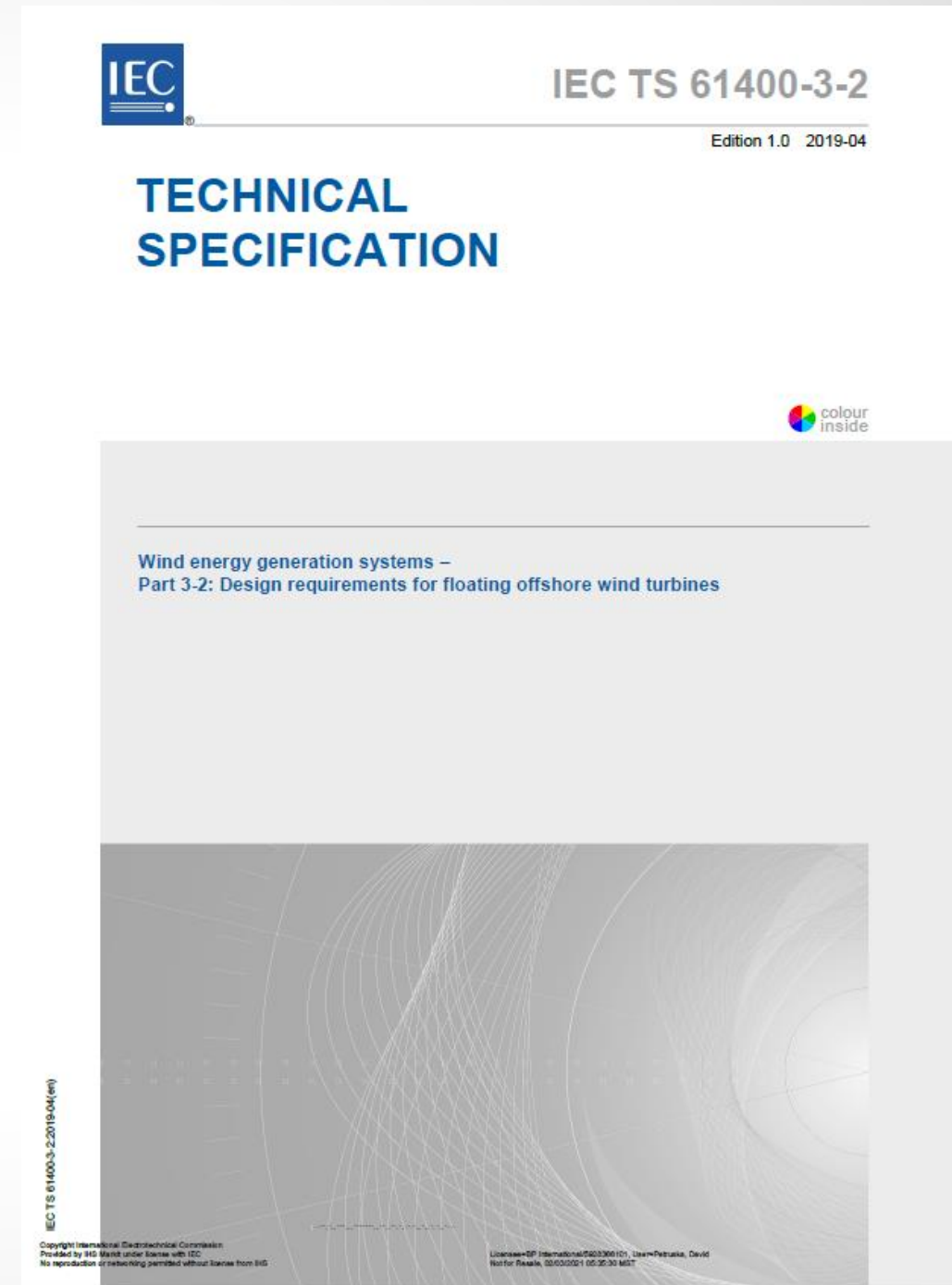
Floating Offshore Wind – Topics



- Site conditions
 - Bathymetry
 - Geohazards
 - Shipping lanes and other hazards
 - Soil conditions and impact on concept selection
 - **Wind source**

Floating Offshore Wind – Topics

- Standards
 - IEC TC88 – wind energy generation systems (61400 series)
 - ❖ IEC TS 61400-3-2 Design requirements for floating offshore wind turbines
 - Largely performance based



Floating Offshore Wind – Topics



- Standards

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61400-1:2019, *Wind energy generation systems – Part 1: Design requirements*

IEC 61400-3-1:2019, *Wind energy generation systems – Part 3-1: Design requirements for fixed offshore wind turbines*

ISO 19901-1:2015, *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 1: Metocean design and operating conditions*

ISO 19901-4:2016, *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 4: Geotechnical and foundation design considerations*

ISO 19901-6:2009, *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 6: Marine operations*

ISO 19901-7:2013, *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 7: Stationkeeping systems for floating offshore structures and mobile offshore units*

ISO 19904-1:2006, *Petroleum and natural gas industries — Floating offshore structures — Part 1: Monohulls, semisubmersibles and spars*

ISO 19906:2010, *Petroleum and natural gas industries – Arctic offshore structures*

IMO Resolution MSC.267(85), *International Code on Intact Stability, 2008 (2008 IS CODE)*

API RP 2FPS: 2011, *Recommended Practice for Planning, Designing, and Constructing Floating Production Systems*

API RP 2T (R2015): 2010, *Recommended Practice for Planning, Designing, and Constructing Tension Leg Platforms*

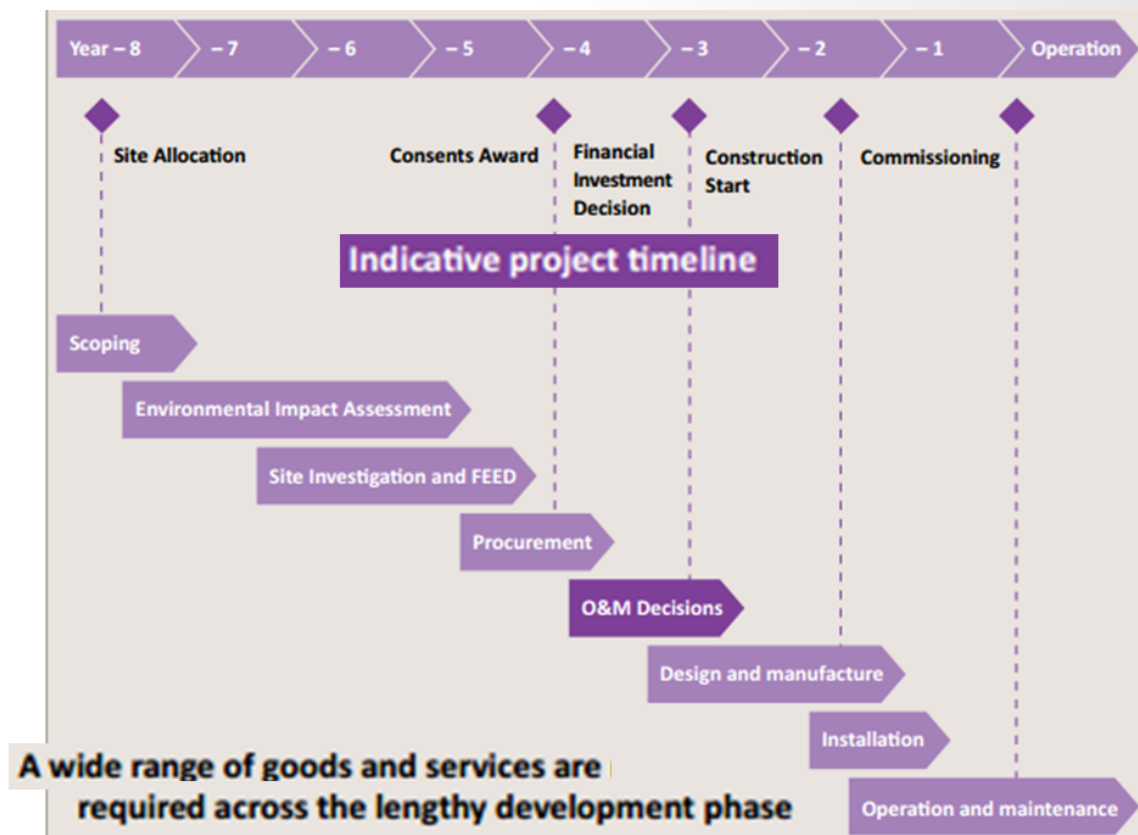
Floating Offshore Wind – Topics

- Standards
 - ISO TC67 Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries
 - IEC TC88 has several ISO TC67/SC7 standards as normative references
 - Discussions started with IEC TC88 about consolidating overlapping activities in offshore wind
 - Will API enter this space also?
 - Risk between the two industries not the same
 - Economics between two industries not the same (O&G gold plating)
 - Guidelines versus standards
 - Does ISO have time to catch-up and keep pace with offshore wind industry
 - Goal based approach for safety standards versus prescriptive standards
 - Industry versus national standards

Floating Offshore Wind – Topics

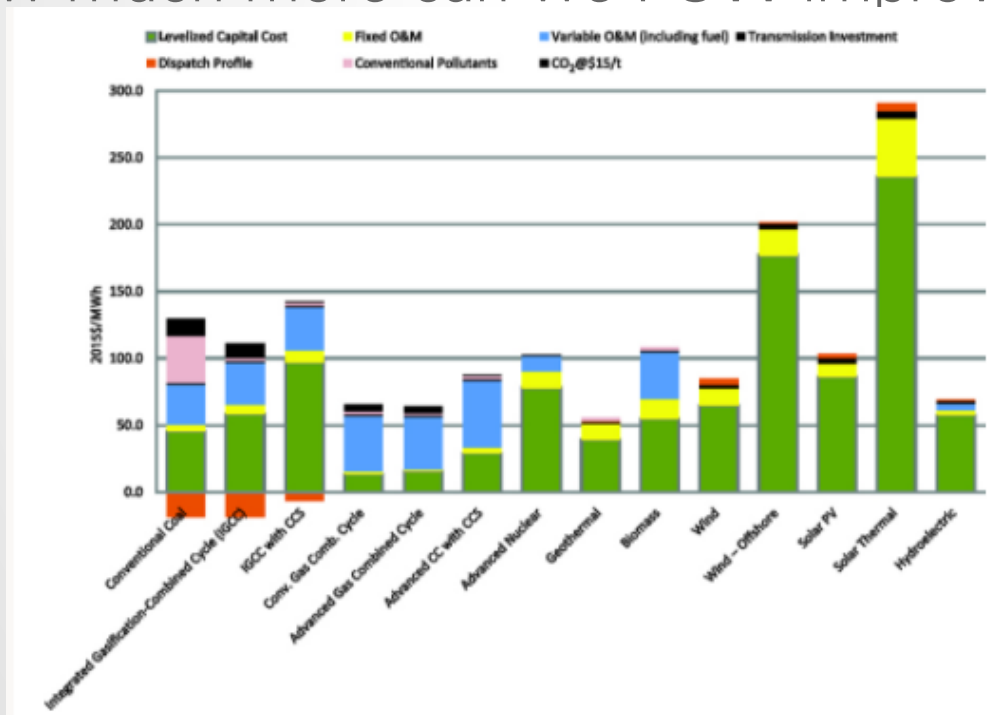


- Lower CAPEX and OPEX
 - Floating wind is just reaching marginally viable cost
 - Continue to look for ways to lower CAPEX and OPEX cost
 - How we build and install
- Schedule
 - Similar to O&G
 - Economics improve with schedule



Floating Offshore Wind – Topics

- LCOE – Key metric
- Floating wind has higher LCOE of most options
- Changing fast for renewables
- How much more can we FOW improve?



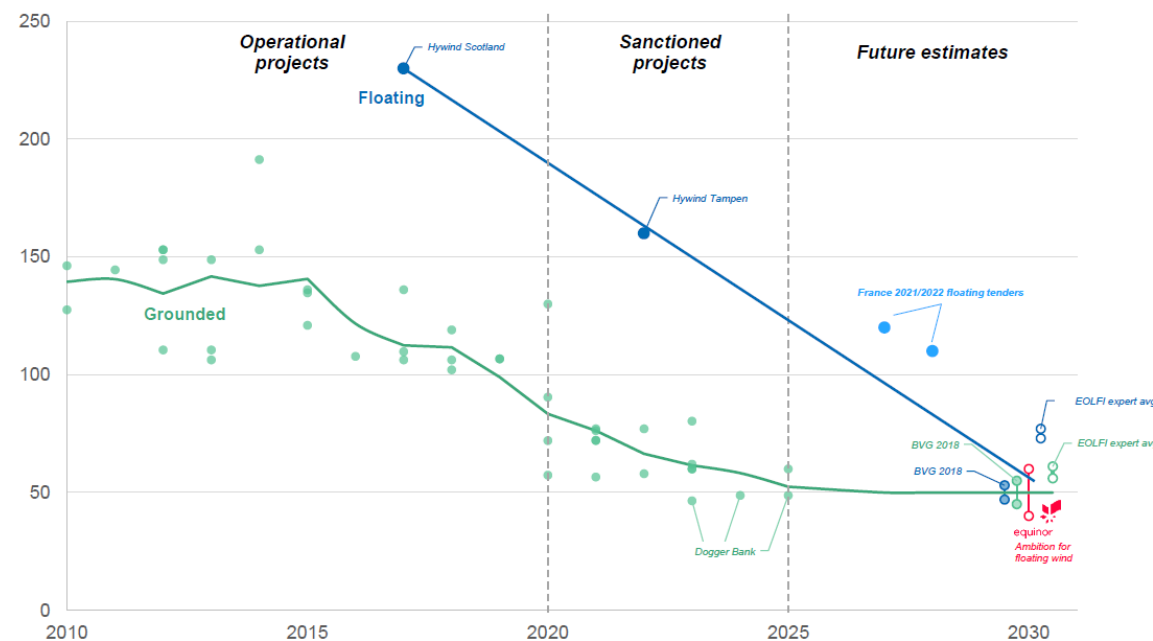
Source: The National Academies Press (left), & IEA 2019 (right)

$$\frac{\sum_{t=1}^n \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^n \frac{E_t}{(1+r)^t}}$$

I_t = Investment expenditures in year t (including financing)
 M_t = Operations and maintenance expenditures in year t
 F_t = Fuel expenditures in year t
 E_t = Electricity generation in year t
 r = Discount rate
 n = Life of the system



LCOE for European offshore wind farms* from 2010 to 2030
 Levelized cost of electricity (LCOE) by start-up year (EUR/MWh)



Floating Offshore Wind – Topics



- Operations
 - Maintenance and inspection
 - Use of OEM, in particular for turbine
 - Risk based inspection plans
 - Sampling versus inspecting entire fleet
 - Vessels to service FOWT
 - How to perform major turbine overhaul/repair without disconnecting and going back to the quay

Floating Offshore Wind – Topics



- Decommissioning
 - To early to fully define
 - Will it follow O&G approach?
 - Will O&G approach be accepted by society when FOW start decommissioning
 - Life extensions to defer for as long as practical?

Floating Offshore Wind – What's next



- A rapidly growing industry in everyway
- Improvements needed
- Role of enabling and emerging technology
- Naval Architect and Marine Engineers will play an important role