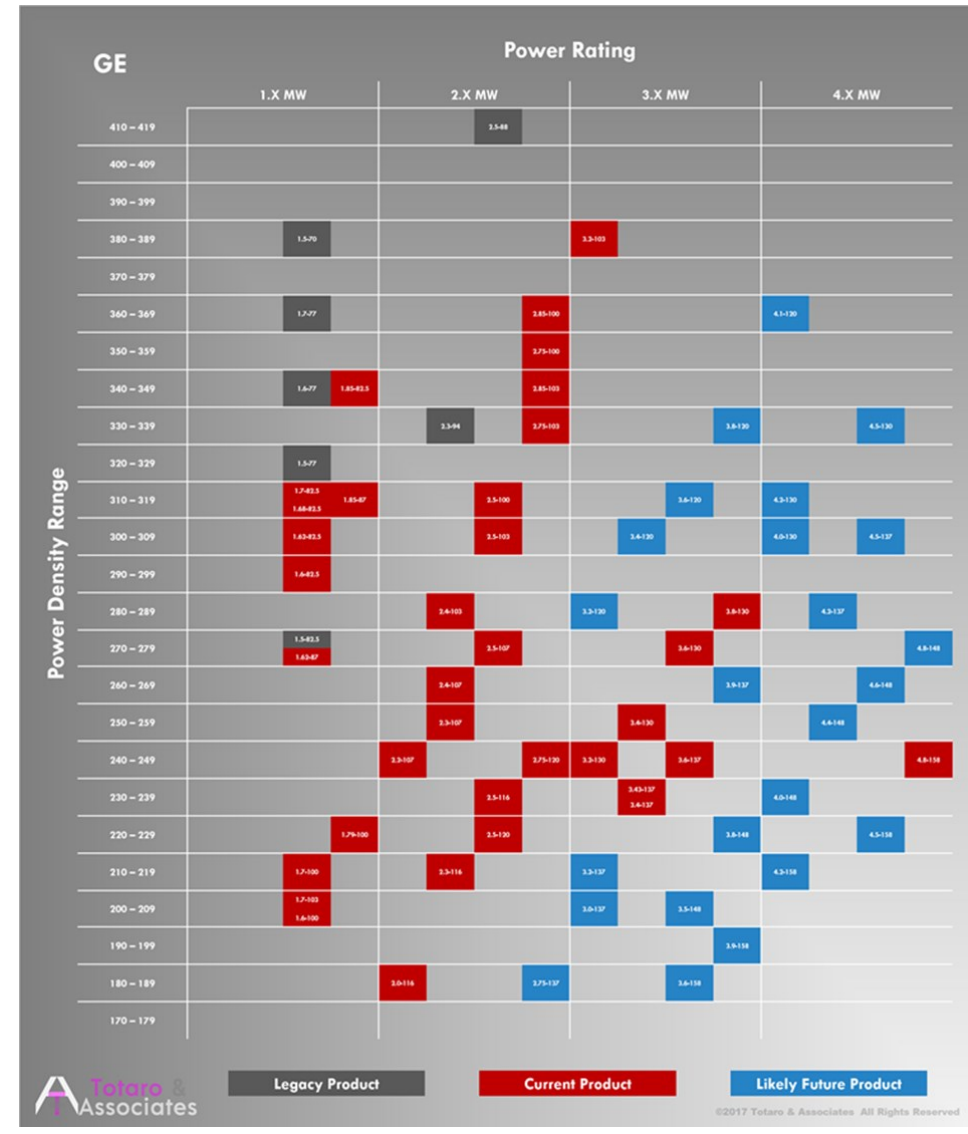
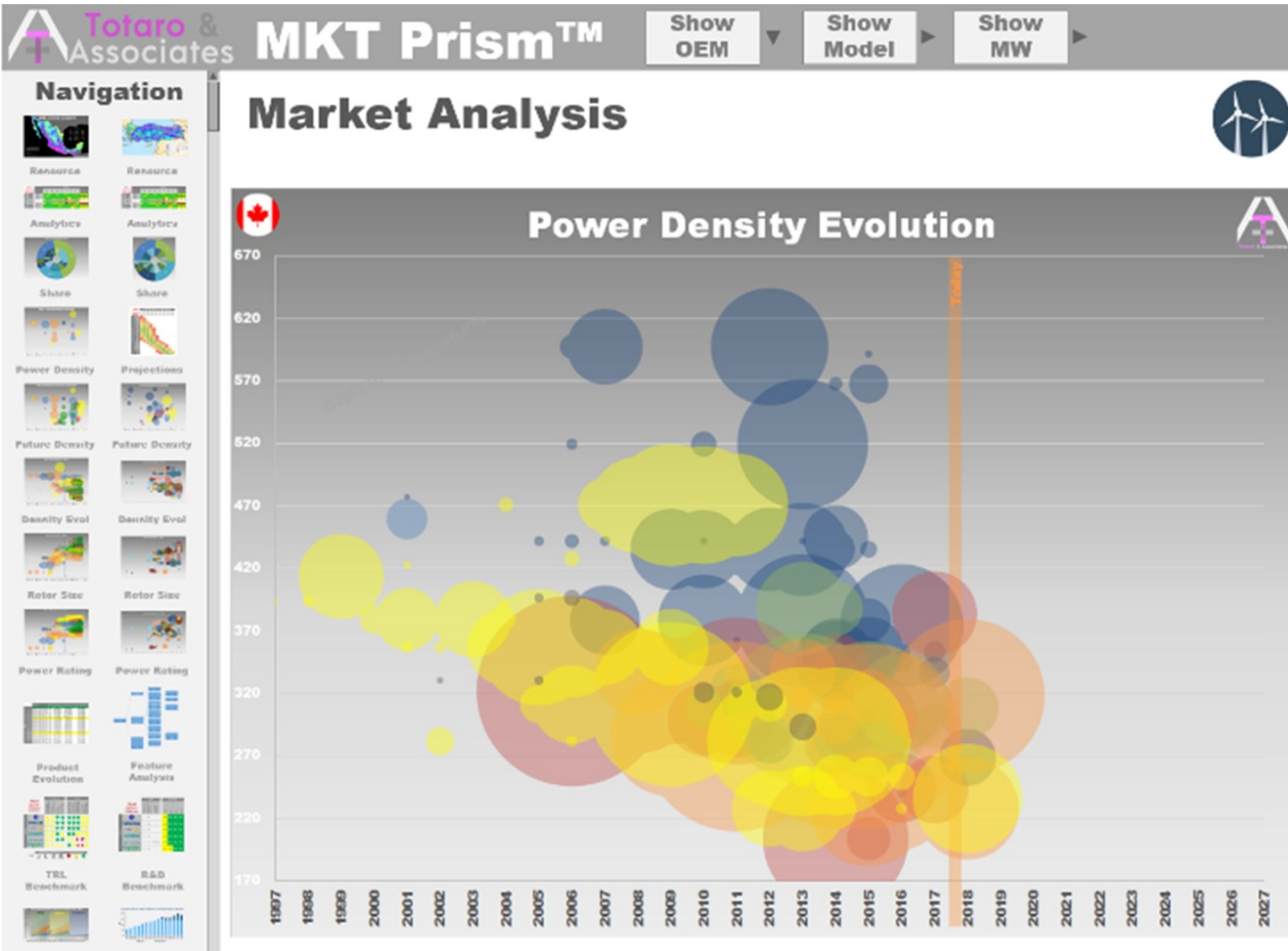


*Τεχνολογικές εξελίξεις στις ανεμογεννήτριες &  
οι δυνατότητες της χώρας να τις αξιοποιήσει*

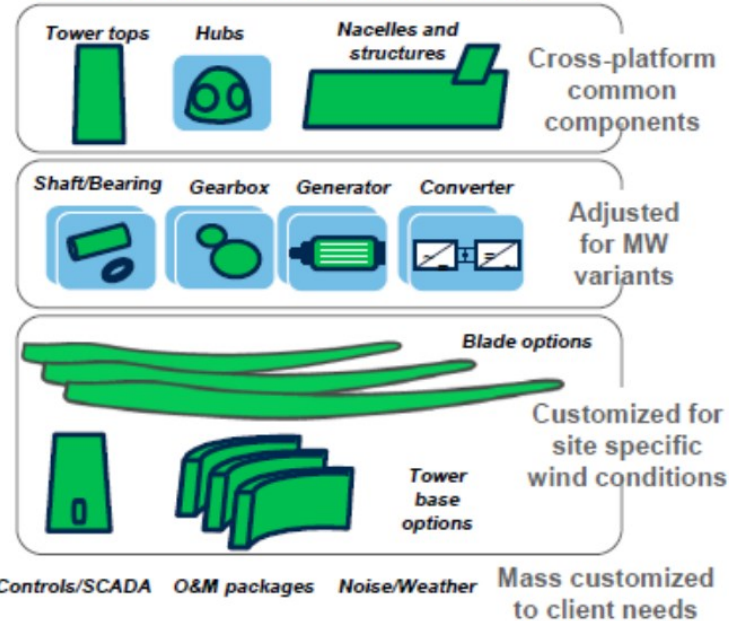
*Π.Κ. Χαβιαρόπουλος  
Εκτελεστικός Διευθυντής iWind*



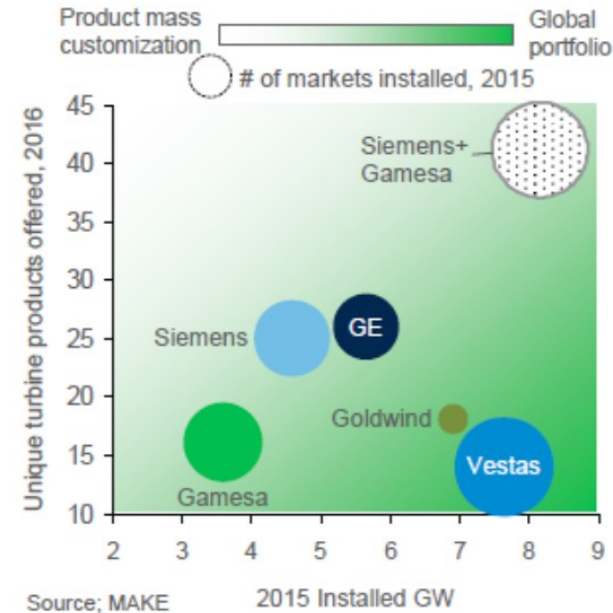
## Global wind turbine technology trends

### Modular product strategies have led to portfolio expansion

#### Mass customization in wind energy

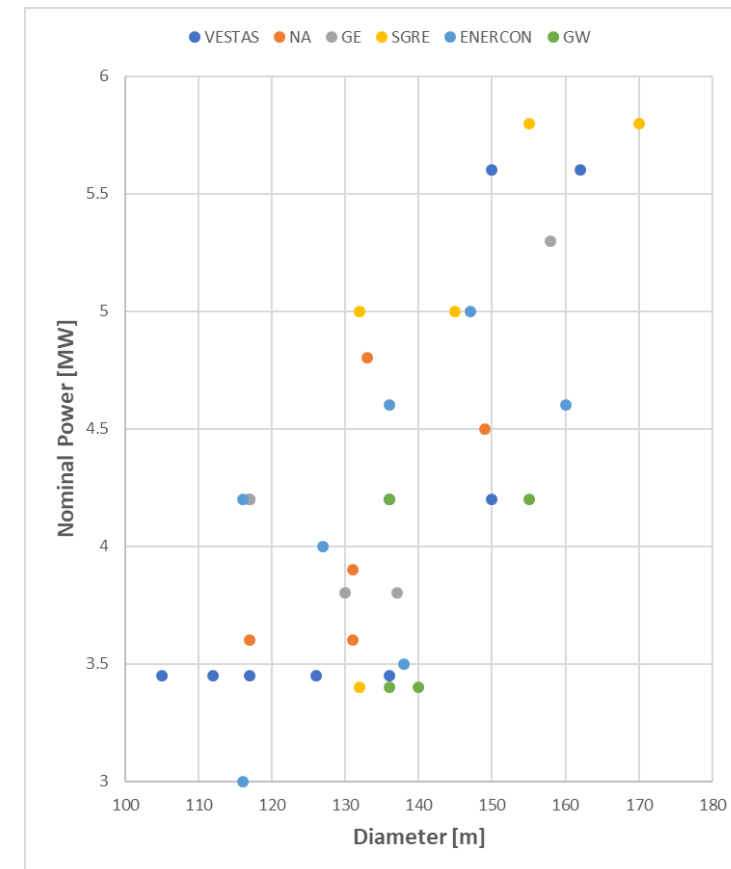


#### OEM portfolio sizes and diversity

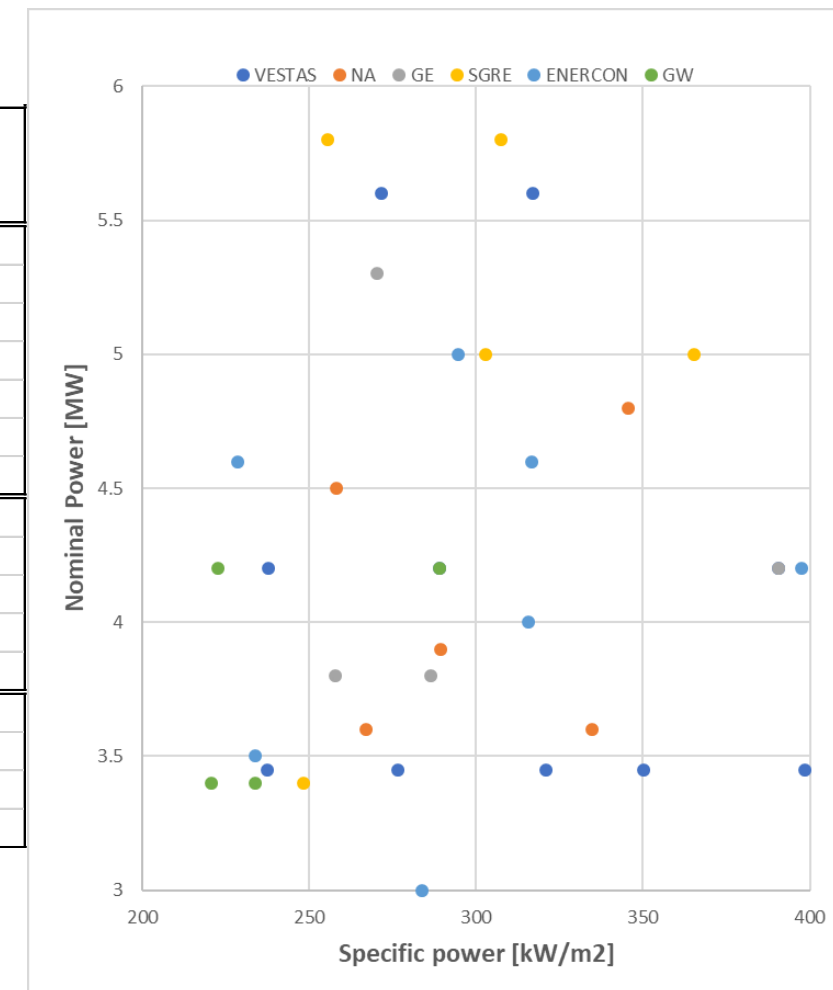


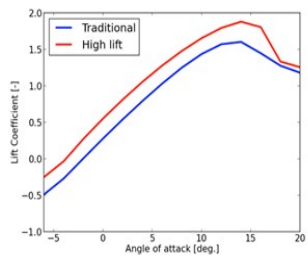
Modular product strategies have enabled strategic component re-use across products  
 Allows for streamlined mass customization to meet global needs and wind conditions

ΚΑΤΑΣΚΕΥΑΣΤΗΣ	ΤΥΠΟΣ Α/Γ	ΙΣΧΥΣ [MW]	ΔΙΑΜΕΤΡΟΣ [m]	Πυκνότητα Ισχύος [W/m <sup>2</sup> ]	ΚΛΑΣΗ IEC	ΥΨΟΣ ΠΛΥΜΝΗΣ [m]	Σύστημα Μετάδοσης	Έλεγχος Ισχύος	Πτερύγια
Vestas	V105	3.45	105	398	IA	72.5	MSG	Pitch (3cyl), VS	
	V112	3.45	112	350	IA/IIA	69/94	HSG	Pitch (3cyl), VS	
	V117	3.45	117	321	IB/IIA	80/91.5/116.5	HSG	Pitch (3cyl), VS	
	V117	4.2	117	391	IB/IIA/S-T	84/91.5	HSG	Pitch (3cyl), VS	
	V126	3.45	126	277	IIIB/IIA	87/117/137/147/149/166	HSG	Pitch (3cyl), VS	
	V136	3.45	136	237	IIIB/IIIA	82/105/112/132/149/166	HSG	Pitch (3cyl), VS	
	V136	4.2	136	289	IIIB/S	site/country specific	HSG	Pitch (3cyl), VS	
	V150	4.2	150	238	IIIB/S	site/country specific	HSG	Pitch (3cyl), VS	
	V150	5.6	150	317	S	105/125/148/155/166	MSG	Pitch (3cyl), VS	
	V162	5.6	162	272	S	119/125/148/166	MSG	Pitch (3cyl), VS	
SiemensGamesa	SG132	3.4	132	248	IA/IIA	84 to 165 & site spec	HSG	Pitch, VS	All GRF
	SG132	5	132	365	IA	84 & site specific	HSG	Pitch, VS	All GRF
	SG145	5	145	303	IIIB	90/102/127/ & site spec	HSG	Pitch, VS	All GRF
	SG155	5.8	155	307	IIA	90/102/122/ & site spec	HSG	Pitch, VS	
	SG170	5.8	170	256	IIIA/IIIB	100/115/135/165	HSG	Pitch, VS	
General Electric	GE117	4.2	117	391	IA/S (57m/s)	85	HSG	Pitch (el. drive), VS	
	GE130	3.8	130	286	I/IIA	85 to 164.5	HSG	Pitch (el. drive), VS	
	GE137	3.8	137	258	III	85 to 164.5	HSG	Pitch (el. drive), VS	
	GE158	5.3	158	270	IIA	101/121/ hybrid 150/161	HSG	Pitch (el. drive), VS	CRF 2Piece

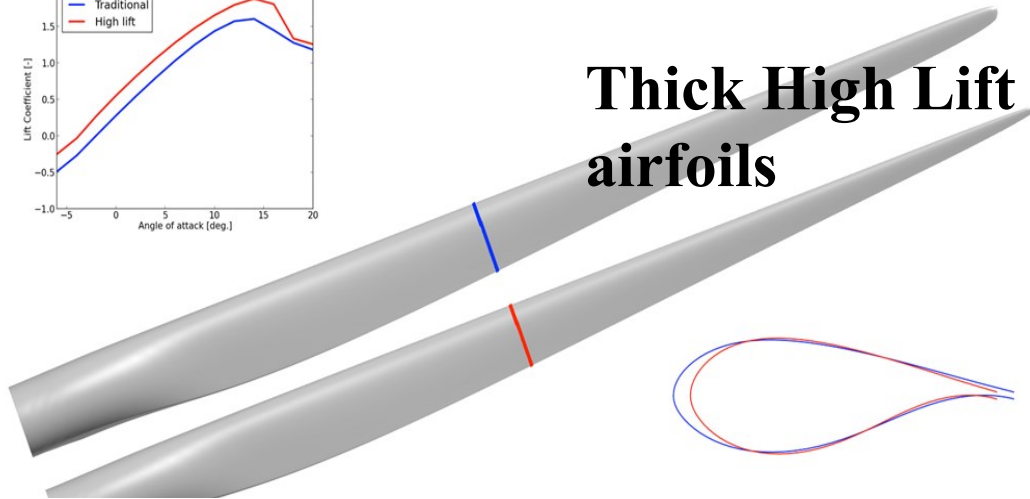


ΚΑΤΑΣΚΕΥΑΣΤΗΣ	ΤΥΠΟΣ Α/Γ	ΙΣΧΥΣ [MW]	ΔΙΑΜΕΤΡΟΣ [m]	Πυκνότητα Ισχύος [W/m <sup>2</sup> ]	ΚΛΑΣΗ IEC	ΥΨΟΣ ΠΛΥΜΝΗΣ [m]	Drive train	Power Control	Blades
Enercon	E115	3	116	284	IIA	92/122/135/149	ELDD	Pitch, VS	
	E115 EP3	4.2	116	397	IA	67/87/92/122/135/149	ELDD	Pitch, VS	
	E126 EP3	4	127	316	IIA	86/116/135	ELDD	Pitch, VS	
	E136 EP5	4.6	136	317	IA	109/120/132/155	ELDD	Pitch, VS	
	E138 EP3	3.5	138	234	IIIA	80/110/130/131/160	ELDD	Pitch, VS	
	E147 EP5	5	147	295	IIA	126/132/143/155	ELDD	Pitch, VS	
	E160 EP5	4.6	160	229	IIIA	120/143/166	ELDD	Pitch, VS	
Nordex	N117	3.6	117	335	IIA	91 to 141	HSG	Pitch, VS	Hybrid
	N131	3.6	131	267	II	84 to 134	HSG	Pitch, VS	Hybrid
	N131	3.9	131	289	III	84 to 134	HSG	Pitch, VS	Hybrid
	N133	4.8	133	346	I/II	78/83/110	HSG	Pitch, VS	Hybrid
	N149	4.5	149	258	II/III	105/125/164	HSG	Pitch, VS	Hybrid
Goldwind	GW136	3.4	136	234	III	100/120	PMDD	Pitch, VS	
	GW136	4.2	136	289	II	100/121	PMDD	Pitch, VS	
	GW140	3.4	140	221	III	100/122	PMDD	Pitch, VS	
	GW155	4.2	155	223	III/S	100 & site spec	PMDD	Pitch, VS	





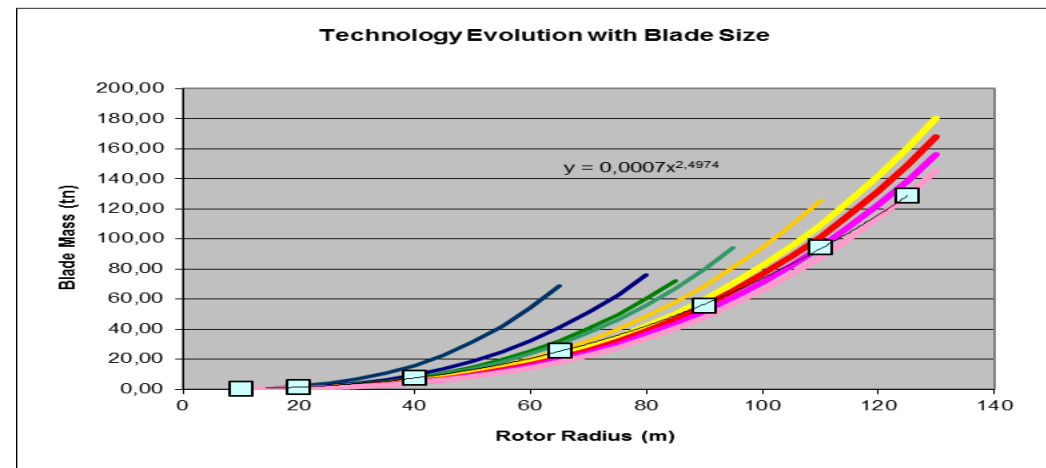
## Thick High Lift airfoils



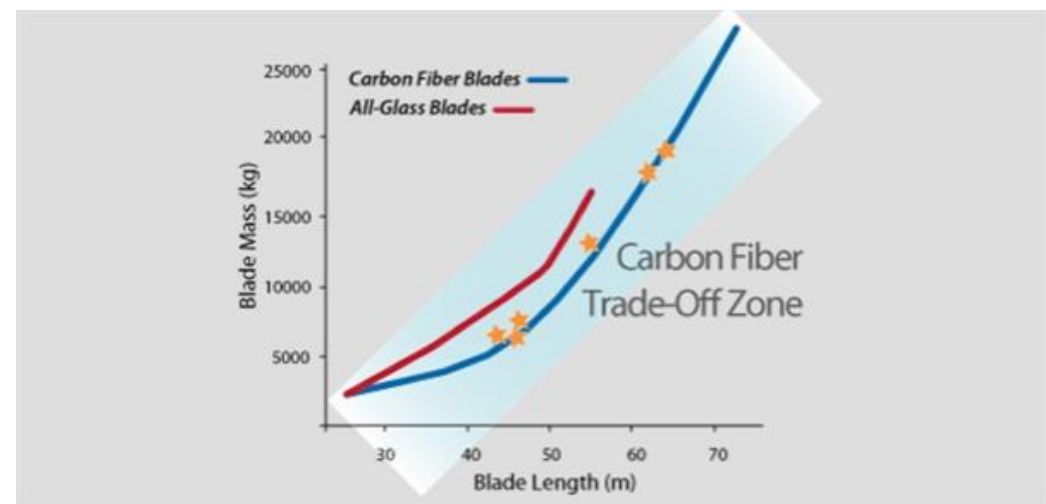
## Planform evolution during the last 30 years

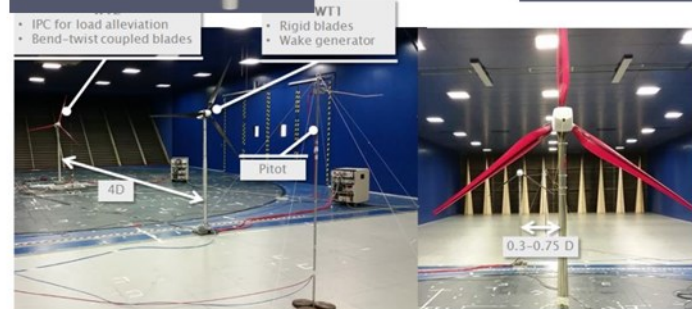
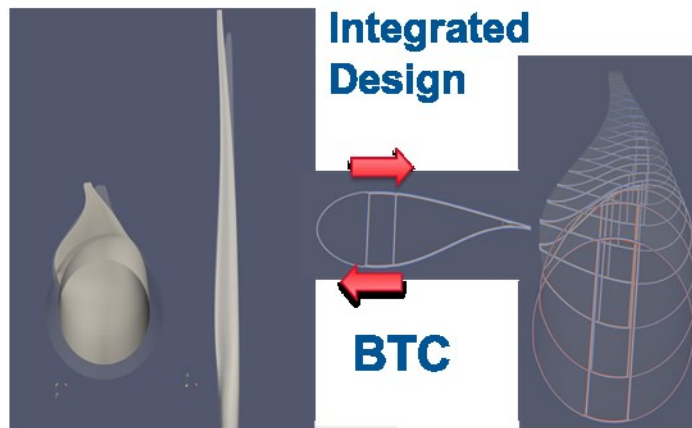
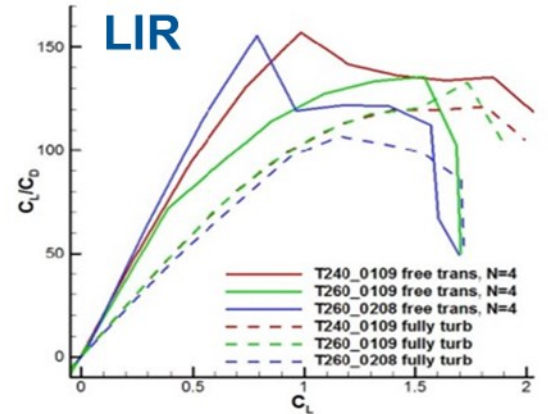
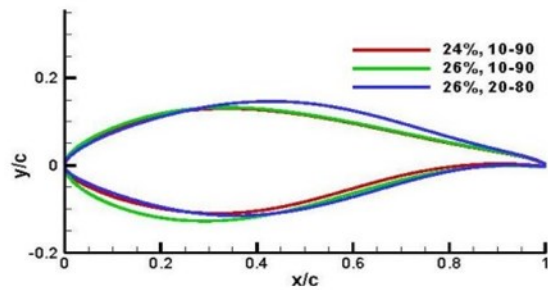


Source DTU IE Report 2014



CRES

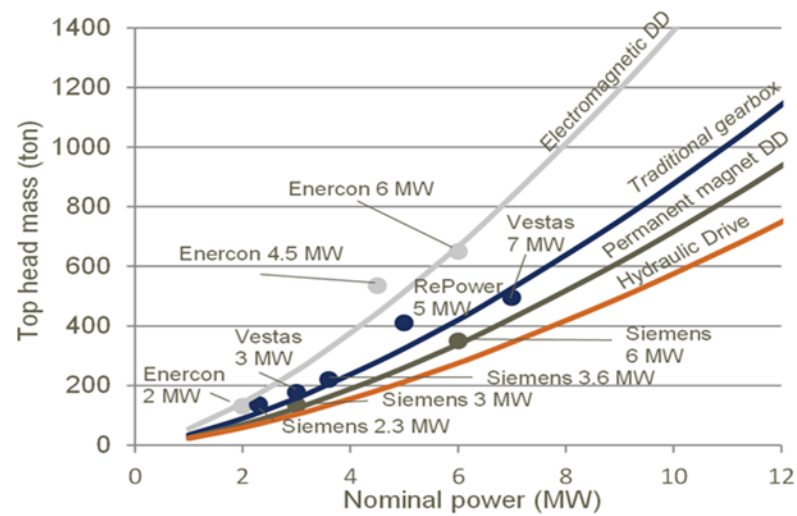




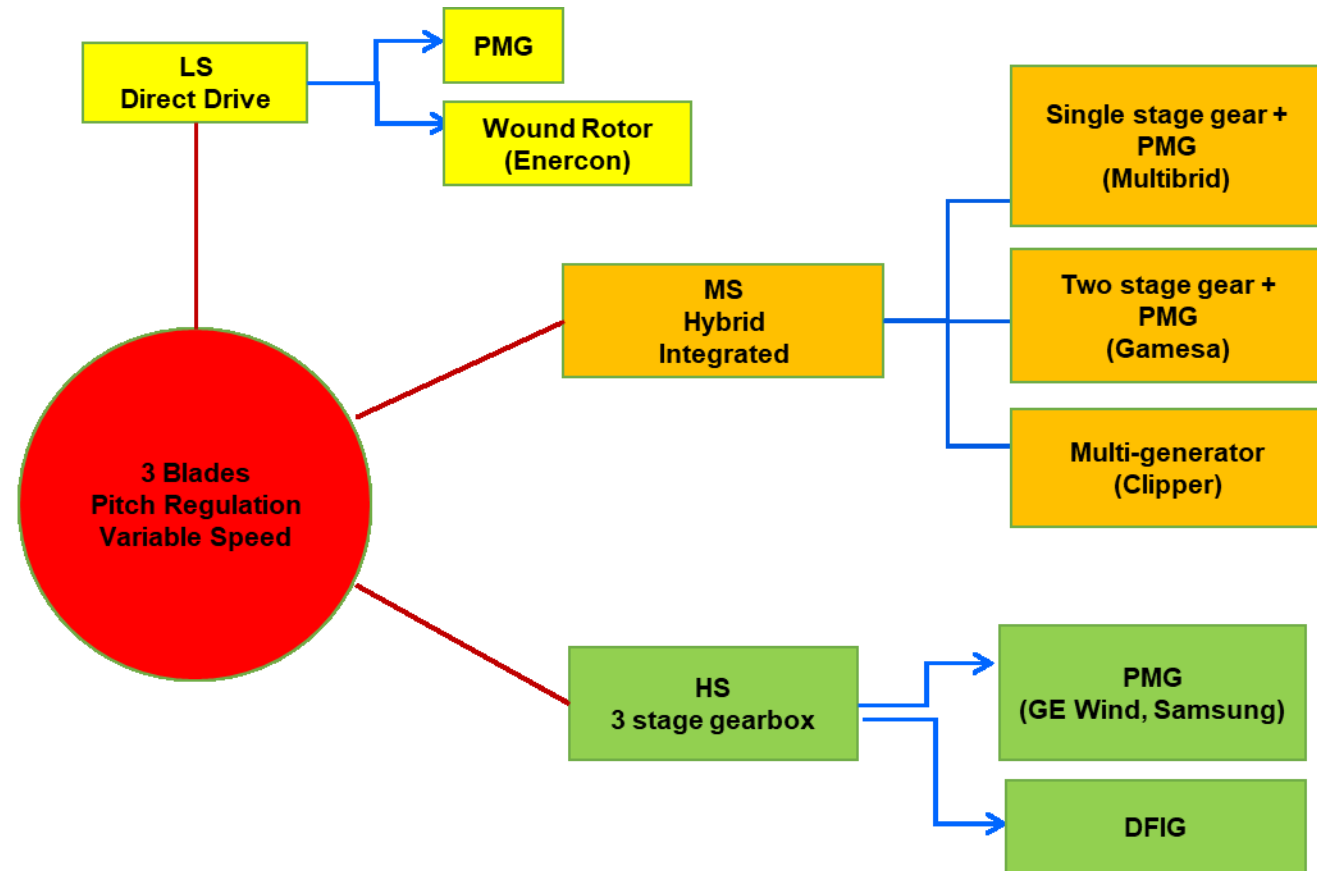
**TE Flaps**



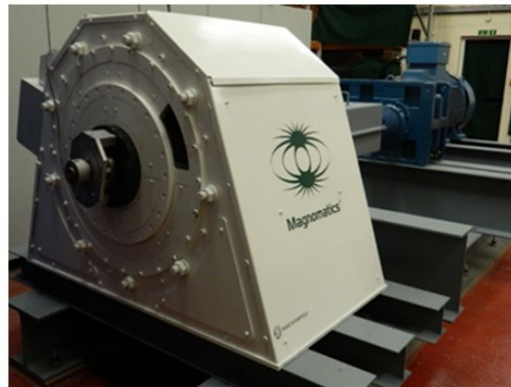
- Ο δρομέας αν και έχει μικρή συμμετοχή στο κόστος της θαλάσσιας Α/Γ έχει την κύρια ευθύνη της ενεργειακής παραγωγής
- Μεγάλοι δρομείς με περιορισμένα/μειωμένα φορτία αποτελούν ζητούμενο για τις μεγάλες θαλάσσιες Α/Γ. Αυτό επιτυγχάνεται με το σχεδιασμό δρομέων μειωμένης επάγωγής (LIR), την αεροελαστική σύζευξη βαθμών ελευθερίας (BTC) και τον ενεργητικό αεροδυναμικό έλεγχο (π.χ. Με πτερύγια καμπυλότητας, flaps)
- Μέθοδοι ολοκληρωμένου αεροελαστικού σχεδιασμού με σημαντικό αριθμό βαθμών ελευθερίας για εξωτερική γεωμετρία και εσωτερική δομή αναπτύχθηκαν και εφαρμόστηκαν κατά κόρον



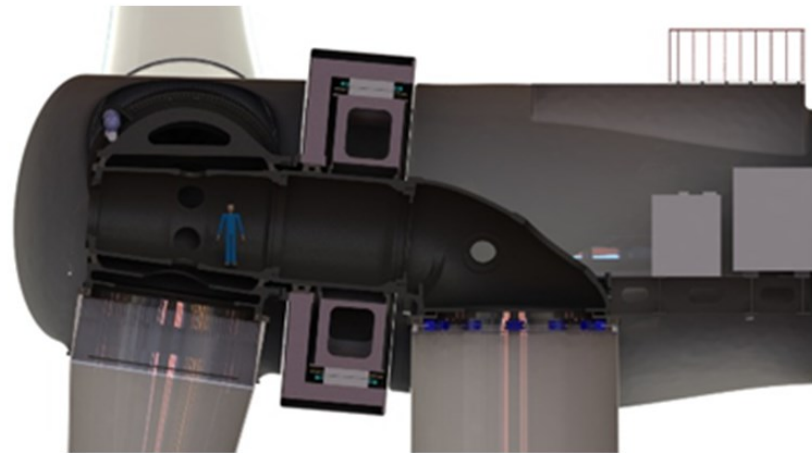
Source BGM Cons



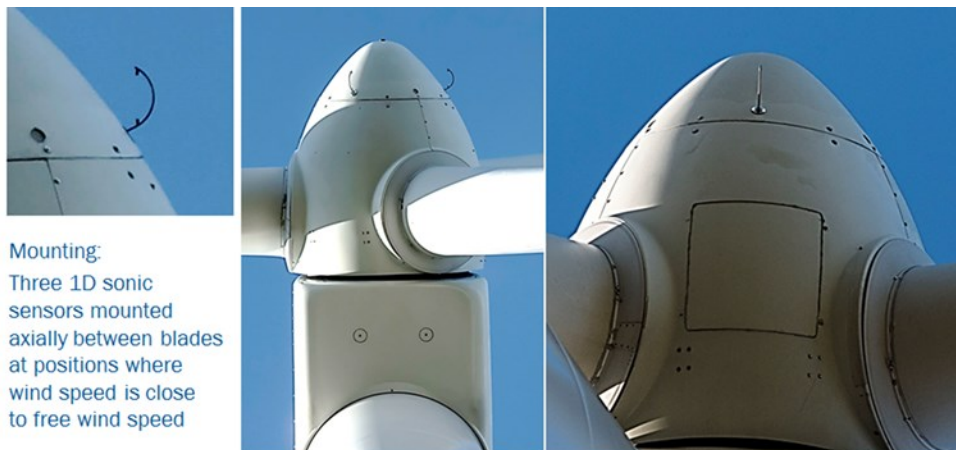




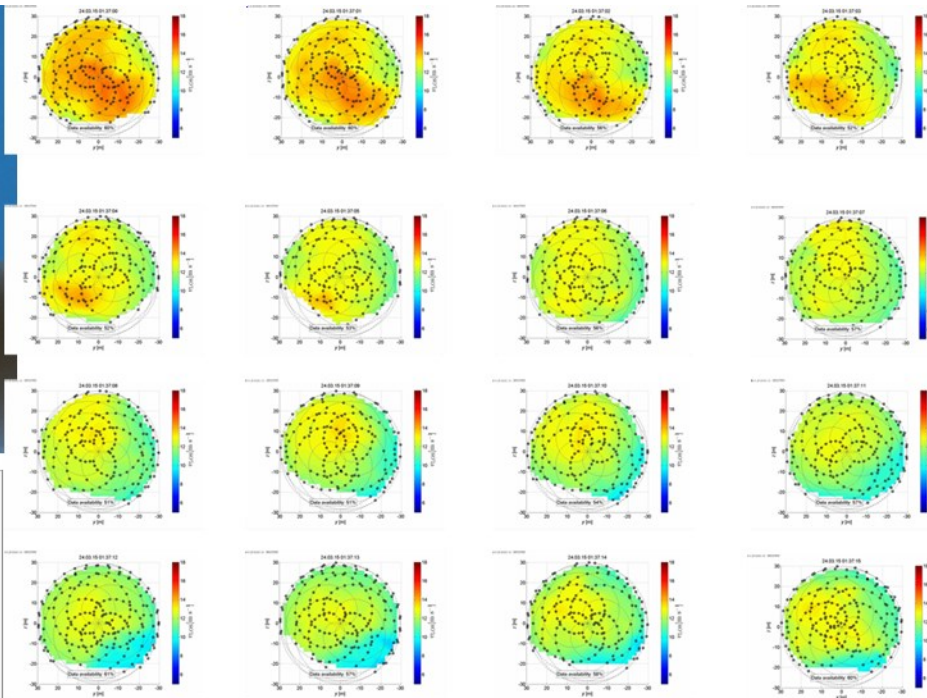
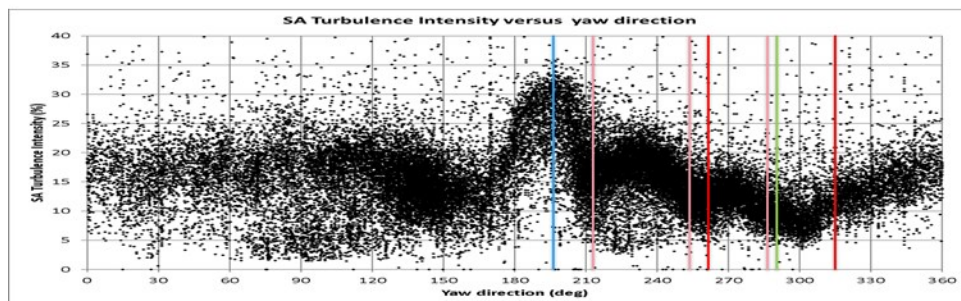
Pseudo-magnetic direct drives (5, 16 and 200 kNm demonstrators)



High-temperature Superconducting generators, MgB<sub>2</sub> race track coil & 20MW concept



Mounting:  
Three 1D sonic  
sensors mounted  
axially between blades  
at positions where  
wind speed is close  
to free wind speed



2D rotor plane wind fields @ 400 measurement points per sec



- Αισθητήρες ταχύτητας ανέμου Spinner Anemometer and Spinner Lidar
- Ανεξάρτητος έλεγχος βήματος και πτερυγίων καμπυλότητας Individual Pitch Control (IPC), Individual Flap Control (IFC) και συνδυασμός τους
- Αυτόματος έλεγχος σε ακραίες τιμές ατμοσφαιρικής τύρβης
- Έξυπνη διακοπή λειτουργίας με χρήση TE Flaps

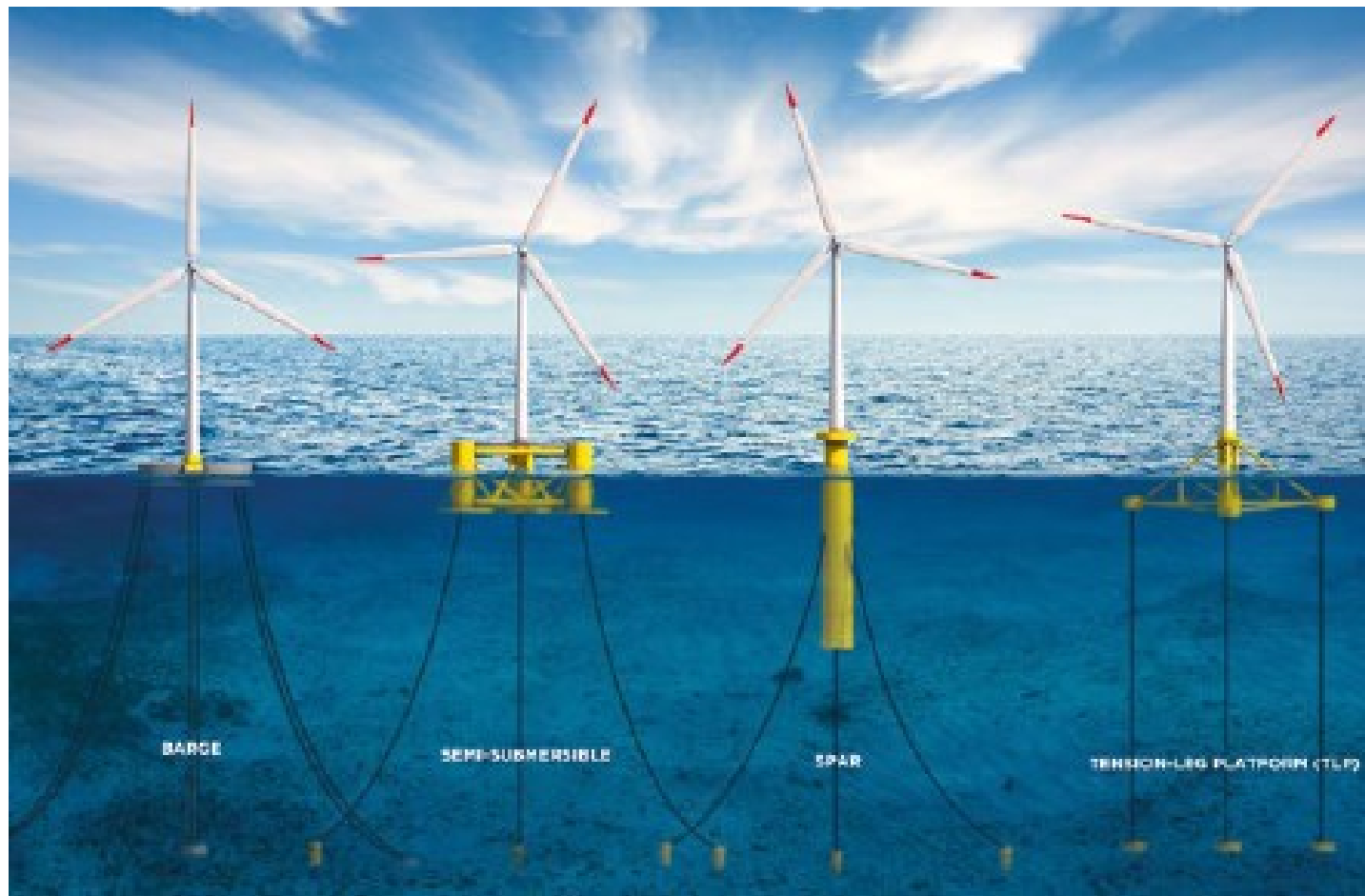
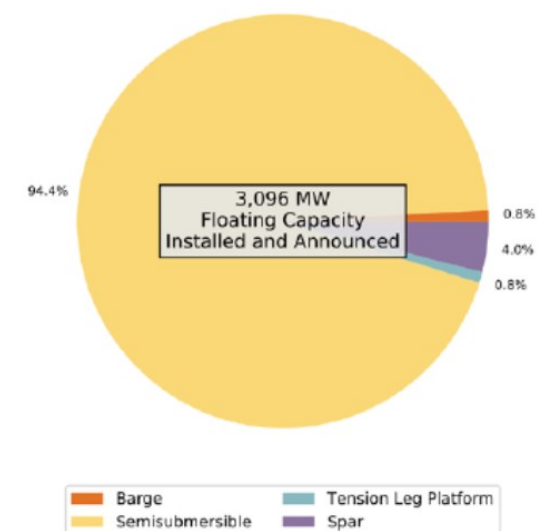


TABLE 2  
Floating offshore wind projects in Europe

PROJECT NAME	CAPACITY	COUNTRY	EXPECTED COMMISSIONING DATE
Dounreay Tri	2 x 5 MW	Scotland	2018
Gaelectic	30 MW	Ireland	2021
Hywind Scotland	30 MW	Scotland	2017
WindFloat Atlantic	30 MW	Portugal	2018-2019
Kincardine	48 MW	Scotland	From 2018
French pre-commercial farms	4 x 25 MW	France	2020
Atlantis / Ideol project	100 MW	UK	2021

Source: WindEurope



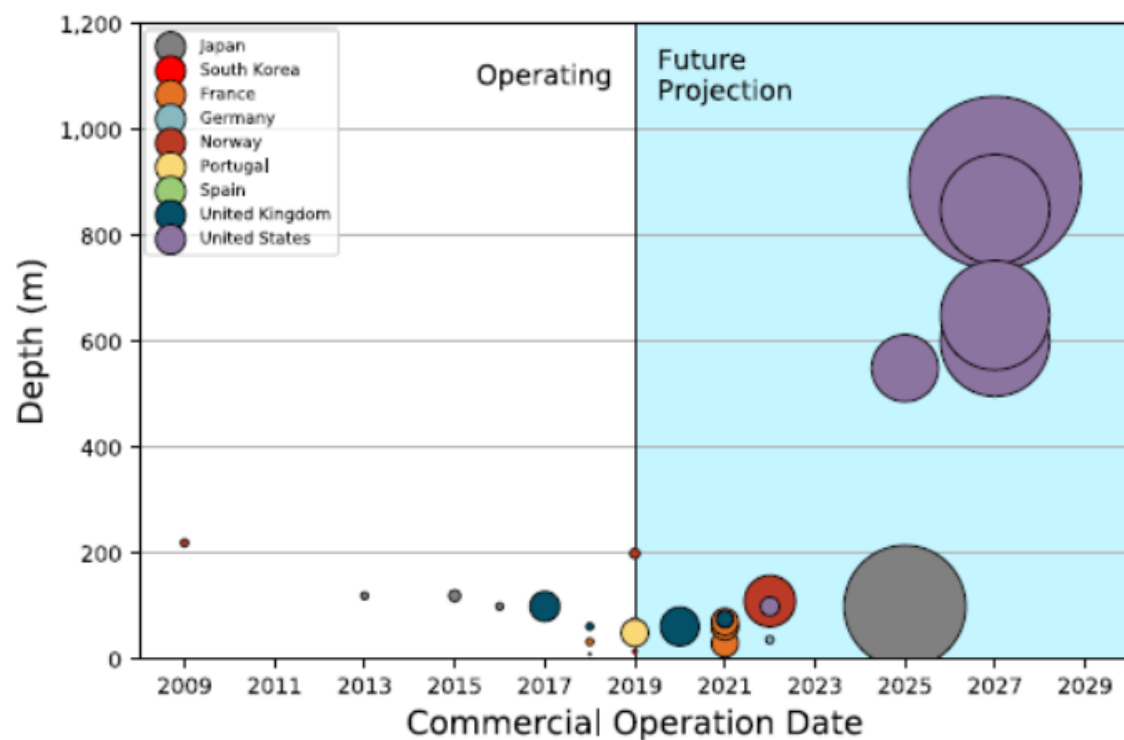


Figure 18. Global floating offshore wind pipeline

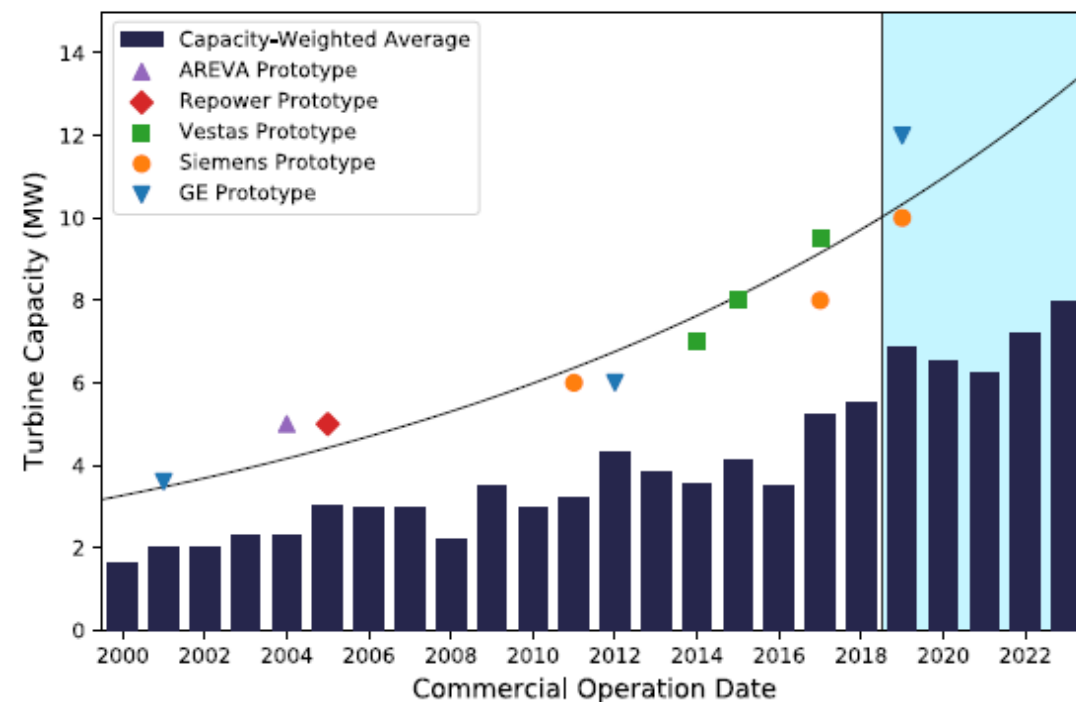
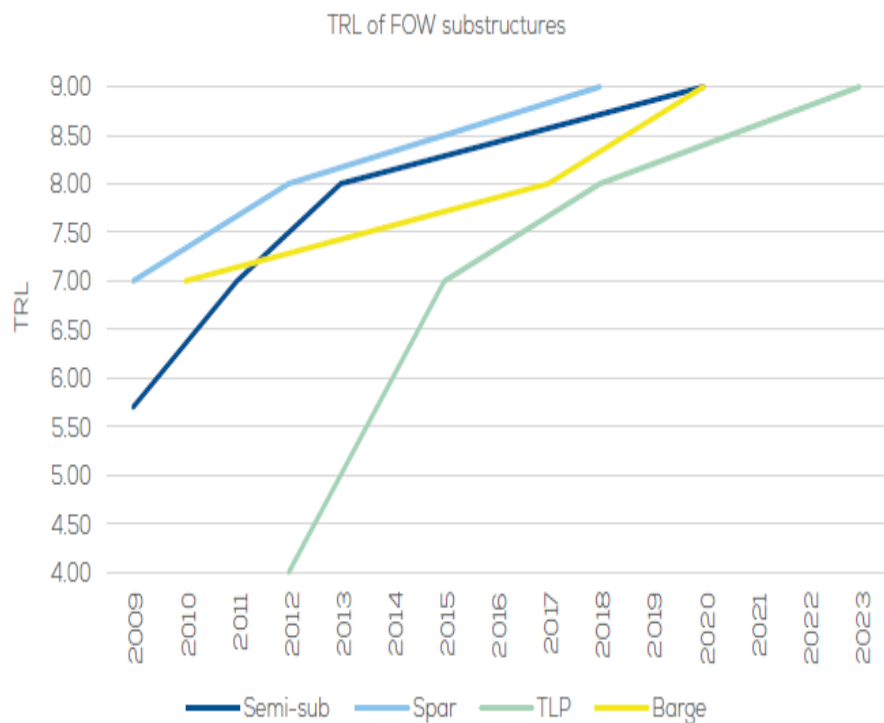


Figure 23. Average commercial offshore wind turbine rating compared to prototype deployment by year

<http://www.osti.gov/scitech>

FIGURE 1  
Technology Readiness Level of Floating Offshore Wind substructures



Source: The Crown Estate<sup>4</sup> and WindEurope

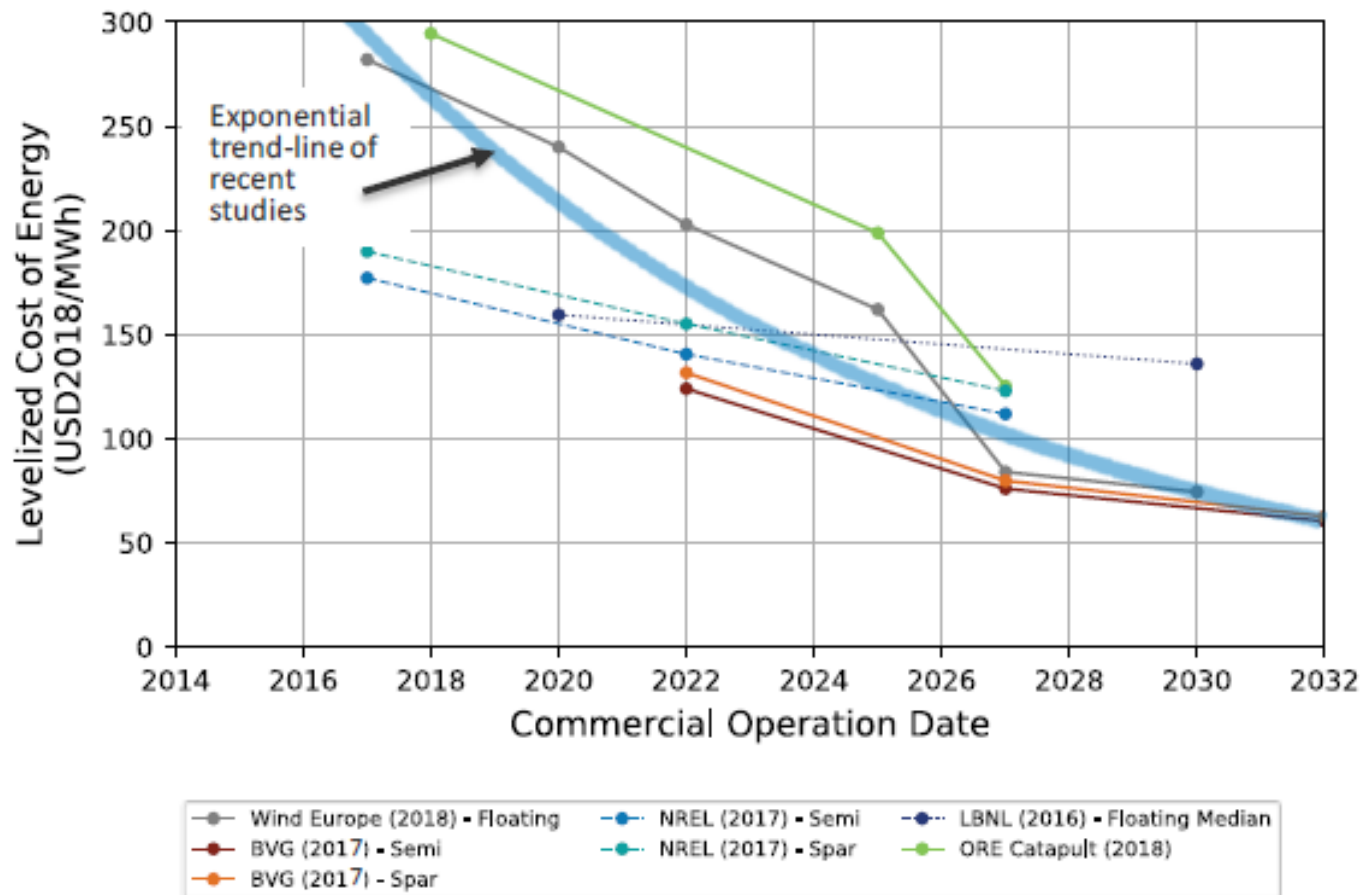


Figure 36. Global LCOE estimates for floating technology<sup>72</sup>

<http://www.osti.gov/scitech>

## Objectives for digitalisation

Source ETIP Wind

### System integration

UNLEASHING THE FULL POTENTIAL OF WIND ENERGY

Variable renewable energy and distributed generation will be key aspects of the future energy system. New data-based tools to increase the connectivity and interactivity between wind farms and the other actors are needed. Cross-sectoral synergies will facilitate the integration of wind in the electricity system.



#### TSO-DSO

More and higher quality data exchanges between system operators and wind power generators will improve the transmission and distribution of clean energy throughout the grid.



#### Real-time grid support capabilities

Enhanced digitalisation will enable wind farms to provide more grid services faster and more efficiently.



#### Synergies with other power generation

Digital solutions connect wind power plants with other power generators, facilitating system-level energy management.



#### Consumer synergies

Digitising electricity consumption and demand-side management will improve consumers' connectivity and interactivity with power generators.



#### Sector coupling

Increased digitalisation offers opportunities to strengthen and develop synergies between the electricity sector and other energy carriers.



#### Storage

Innovative systems coupling wind power and storage will enhance wind's ability to become a crucial part of the energy system.

### Reducing Costs

PRODUCING CHEAPER AND AFFORDABLE CLEAN ENERGY

Wind is increasingly competitive with conventional energy sources but needs innovative digital solutions to continue its growth. New data-driven designs and strategies will bring the cost of wind energy further down and, at the same time, improve the value of wind power.



#### Improving productivity

Enhanced forecasting and smarter control through digitalisation will enable turbines to create more energy.



#### Decreasing O&M cost (OPEX)

Improved decision making based on data analytics will enhance daily operations and maintenance, decreasing the MWh production cost.



#### Decreasing investment cost (CAPEX)

Data-driven design of wind turbines and new construction and manufacturing techniques will decrease investments cost and avoid over-engineering.



#### Lifetime extension

Digitalisation help develop smart materials and tailor-made operation and maintenance strategies that extend turbines' lifetime.



#### Improving the value of each MWh produced

Better operations and trading through data-driven analyses of the power markets will boost the value of wind power production.

- Digital twins / digital clones
- Enhanced forecasting & smarter control
- Decision making based on data analytics
- Data-driven design decreases CAPEX
- Lifetime extension through tailored-made O&M
- Better operation & trading