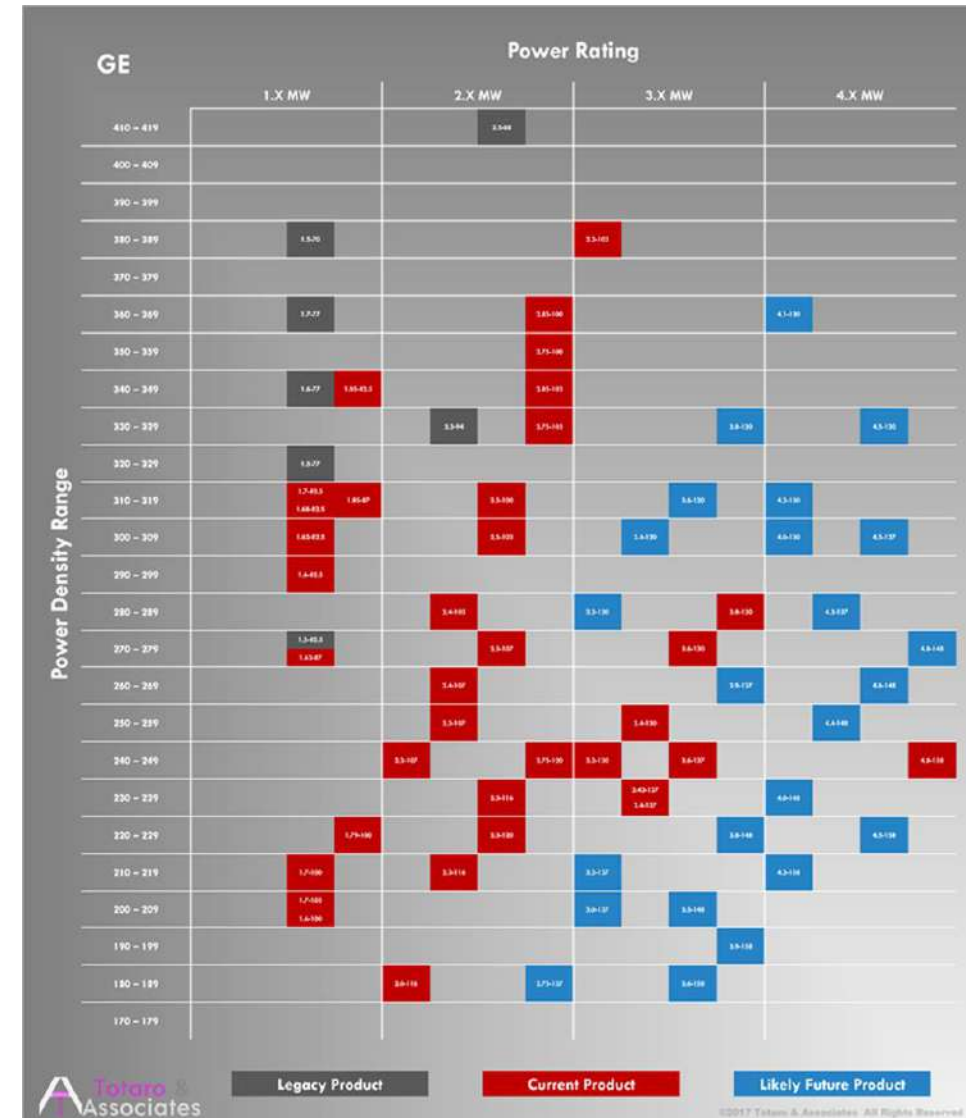
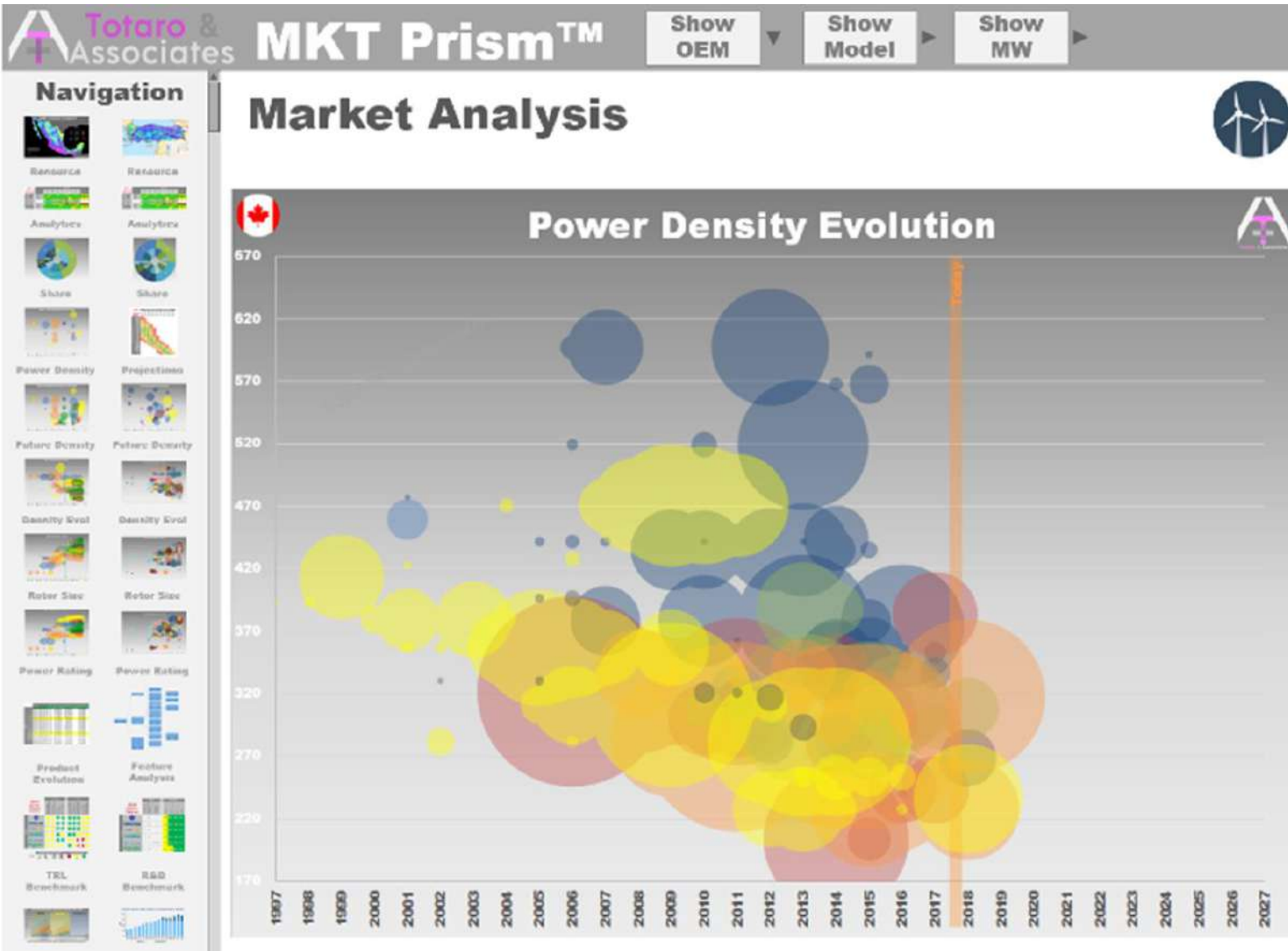


*Τεχνολογικές εξελίξεις στις ανεμογεννήτριες &  
οι δυνατότητες της χώρας να τις αξιοποιήσει*

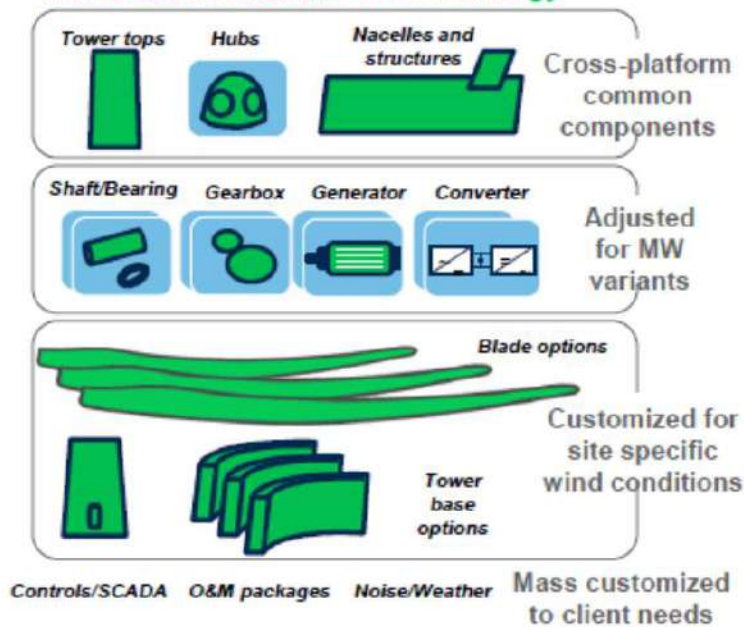
*Π.Κ. Χαβιαρόπουλος  
Εκτελεστικός Διευθυντής iWind*



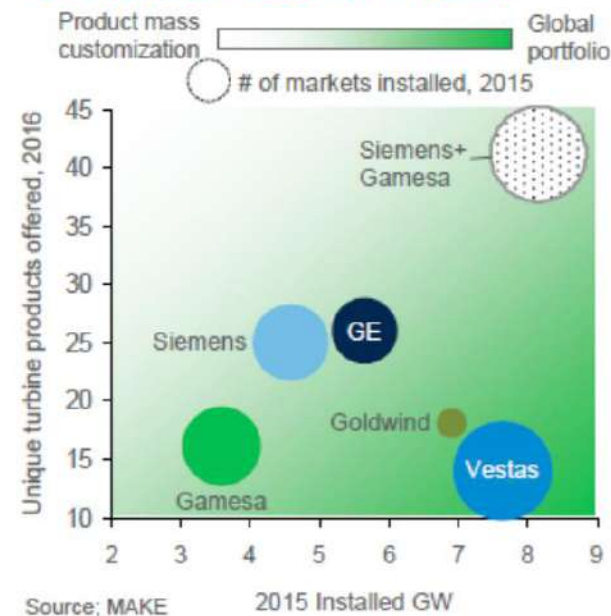
## Global wind turbine technology trends

### Modular product strategies have led to portfolio expansion

#### Mass customization in wind energy



#### OEM portfolio sizes and diversity



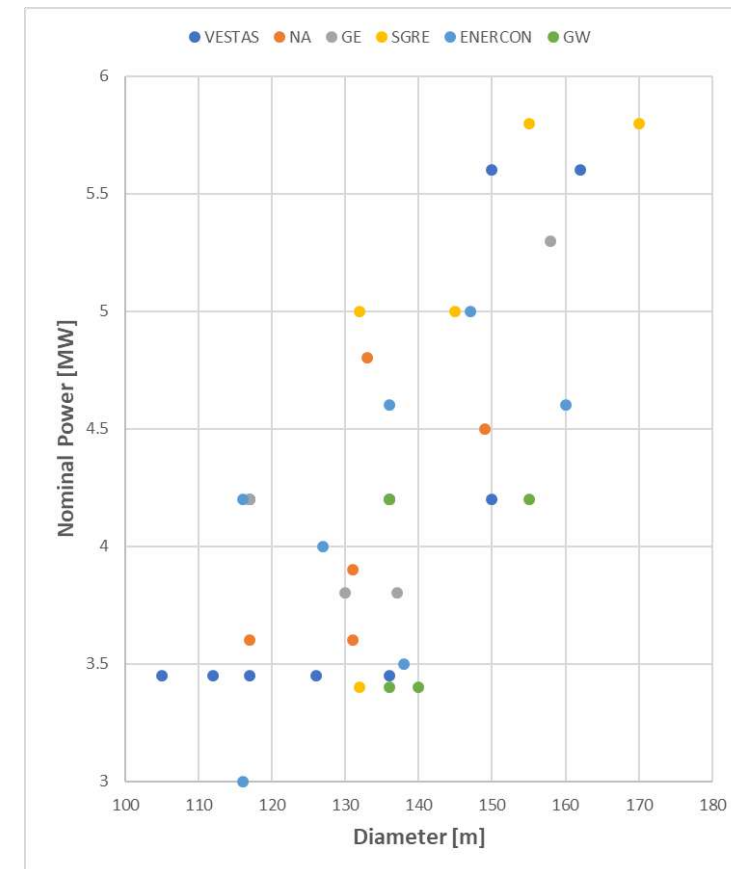
Modular product strategies have enabled strategic component re-use across products  
Allows for streamlined mass customization to meet global needs and wind conditions



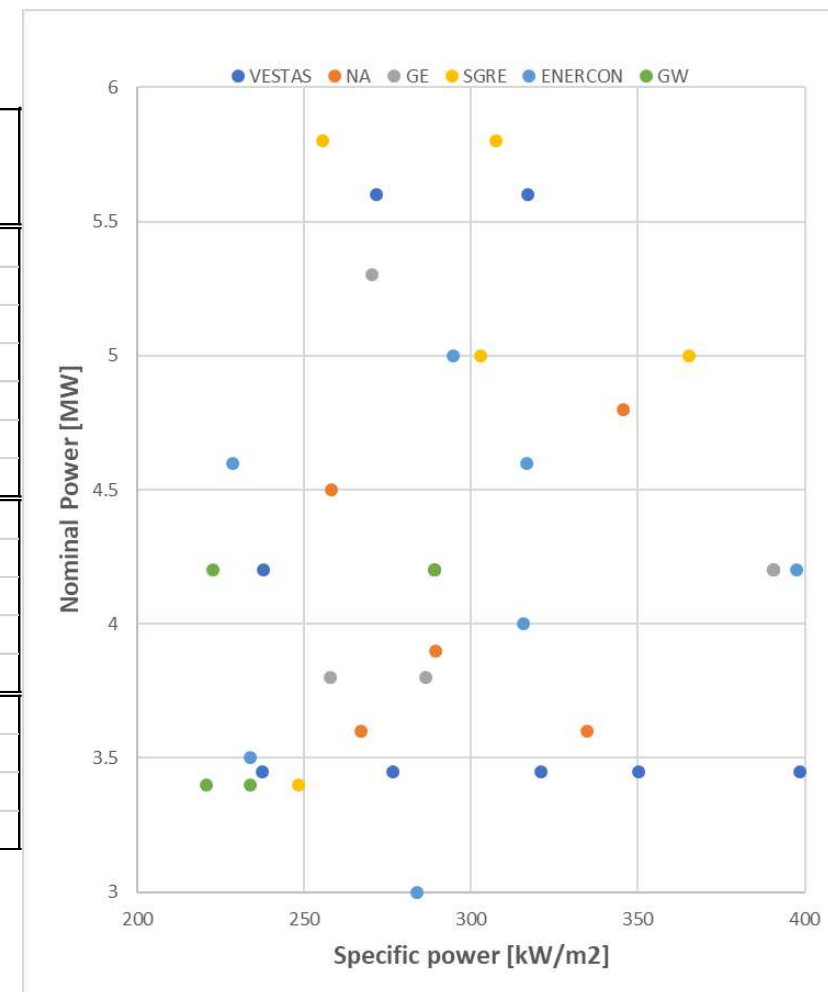
MAKE

Delivering renewable  
energy insight™

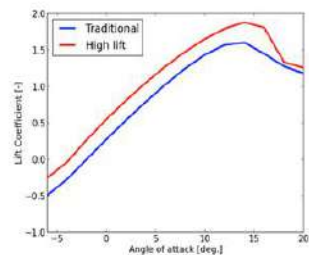
| ΚΑΤΑΣΚΕΥΑΣΤΗΣ    | ΤΥΠΟΣ Α/Γ | ΙΣΧΥΣ [MW] | ΔΙΑΜΕΤΡΟΣ [m] | Πυκνότητα Ισχύος [W/m <sup>2</sup> ] | ΚΛΑΣΗ IEC    | ΥΨΟΣ ΠΛΥΜΝΗΣ [m]        | Σύστημα Μετάδοσης | Ελεγχος Ισχύος        | Πτερύγια   |
|------------------|-----------|------------|---------------|--------------------------------------|--------------|-------------------------|-------------------|-----------------------|------------|
| 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                                  | IIB/IIA      | 87/117/137/147/149/166  | HSG               | Pitch (3cyl), VS      |            |
|                  | V136      | 3.45       | 136           | 237                                  | IIB/IIIA     | 82/105/112/132/149/166  | HSG               | Pitch (3cyl), VS      |            |
|                  | V136      | 4.2        | 136           | 289                                  | IIB/S        | site/country specific   | HSG               | Pitch (3cyl), VS      |            |
|                  | V150      | 4.2        | 150           | 238                                  | IIB/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                                  | IIB          | 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/IIB     | 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 |



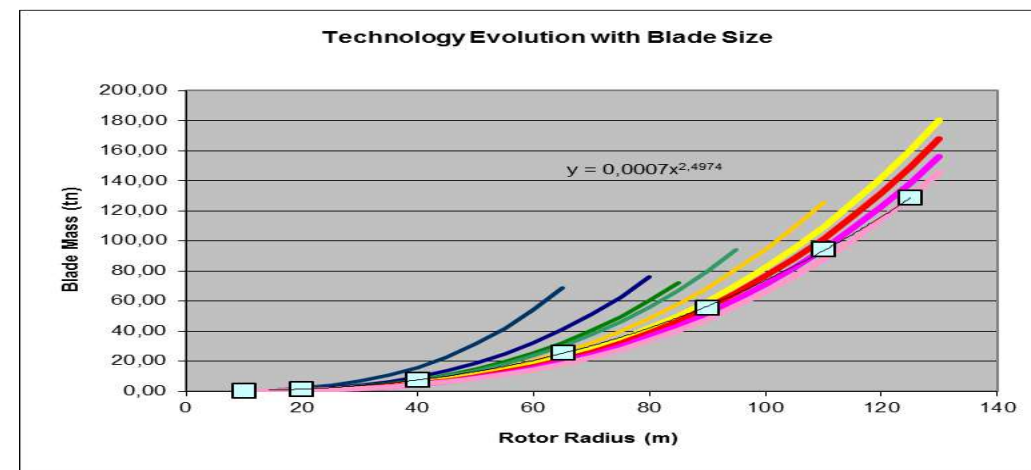
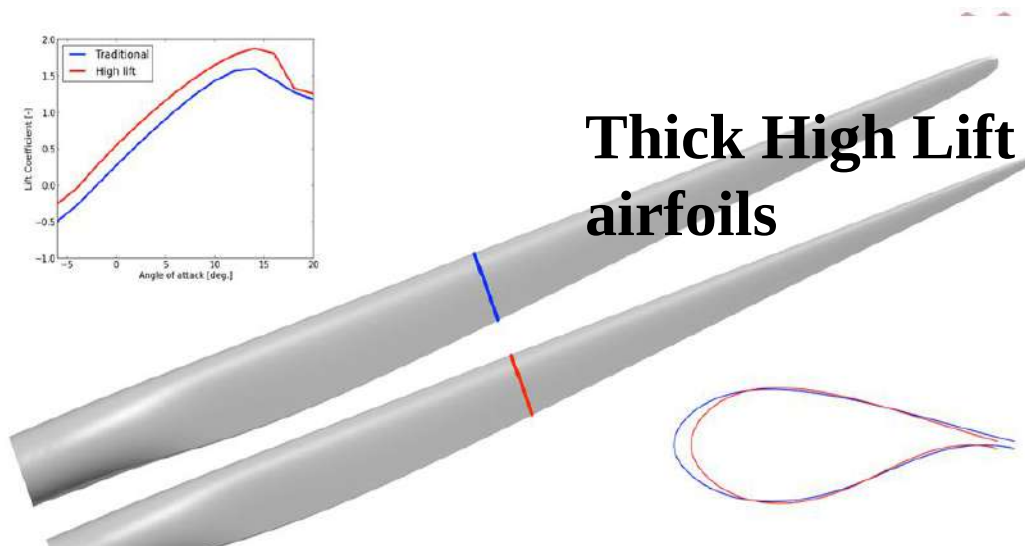
| ΚΑΤΑΣΚΕΥΑΣΤΗΣ | ΤΥΠΟΣ Α/Γ | ΙΣΧΥΣ [MW] | ΔΙΑΜΕΤΡΟΣ [m] | Πυκνότητα Ισχύος [W/m <sup>2</sup> ] | ΚΛΑΣΗ IEC | ΥΨΟΣ ΠΛΥΜΝΗΣ [m]     | Drive train | Power Control | Blades |
|---------------|-----------|------------|---------------|--------------------------------------|-----------|----------------------|-------------|---------------|--------|
| 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**

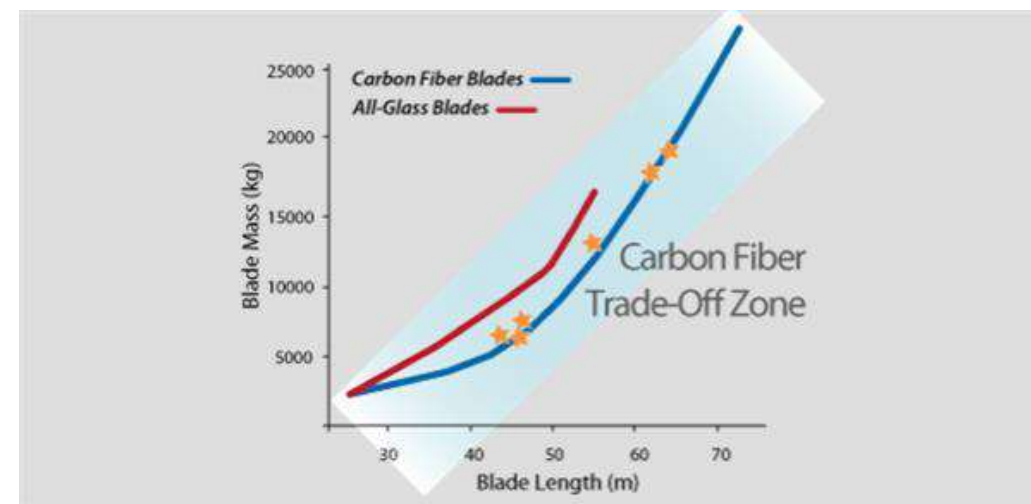


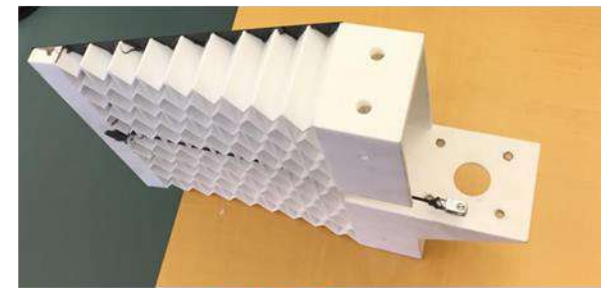
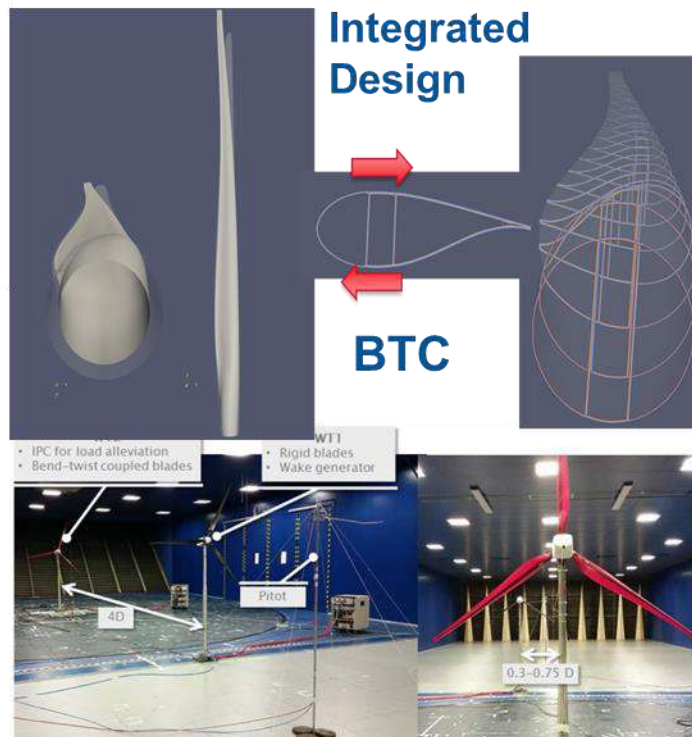
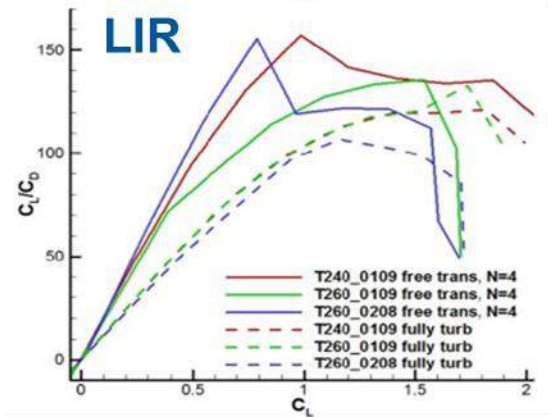
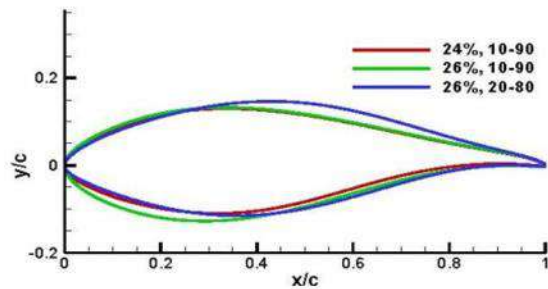
**CRES**

**Planform evolution during the last 30 years**



Source DTU IE Report 2014

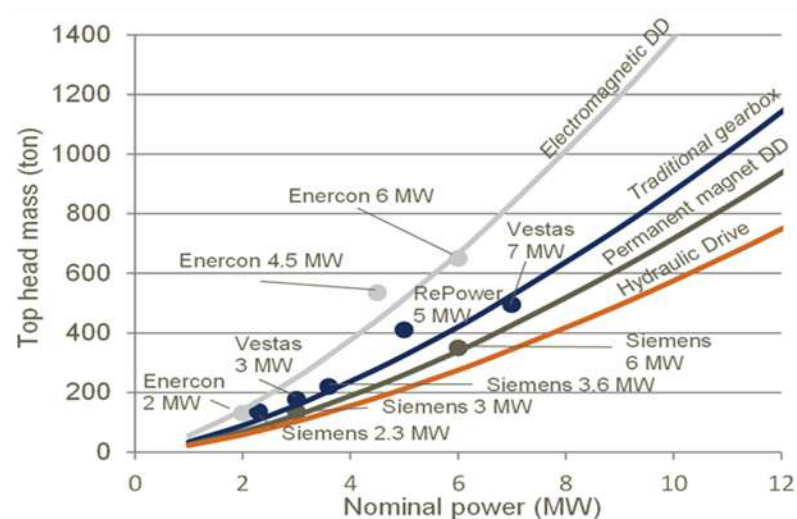




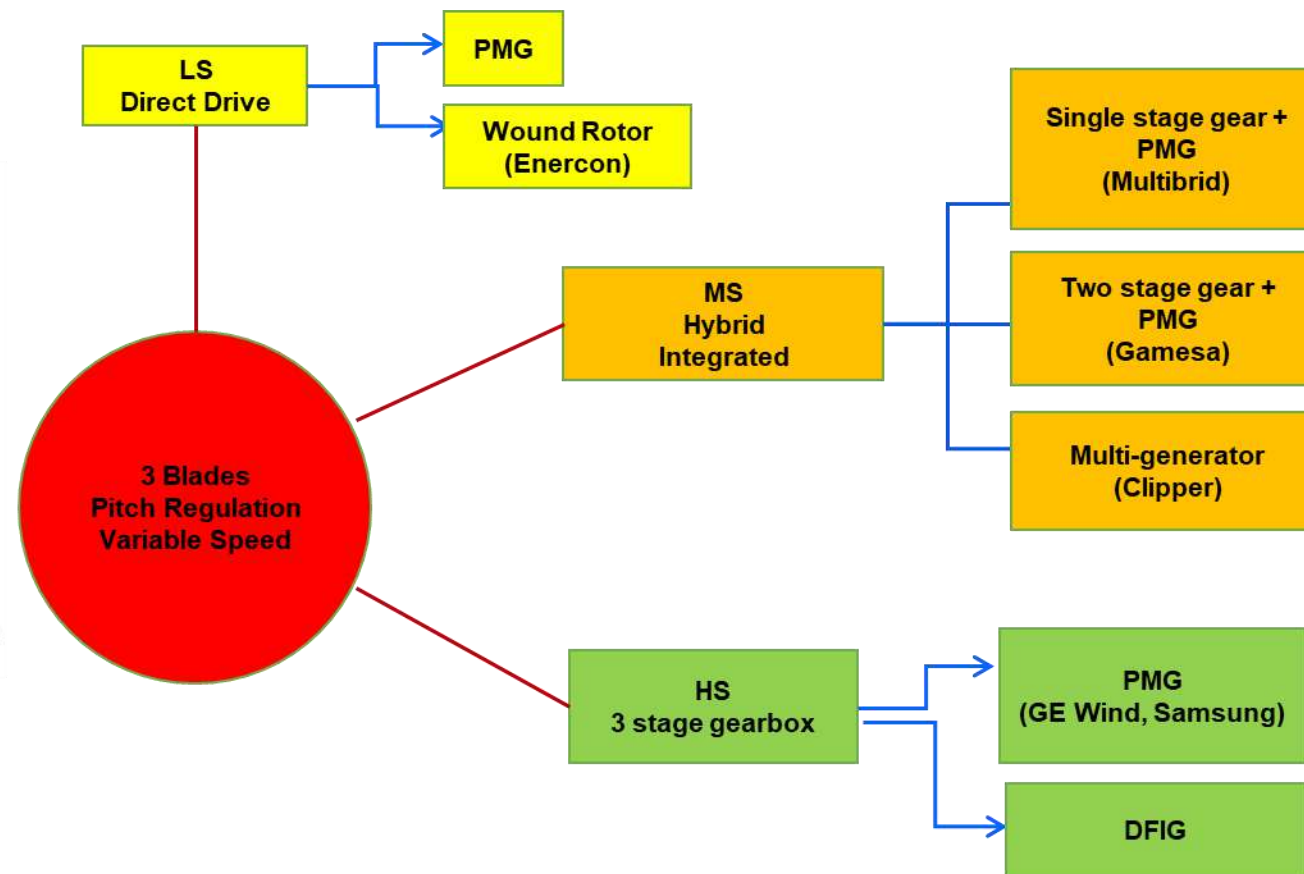
TE Flaps



- 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

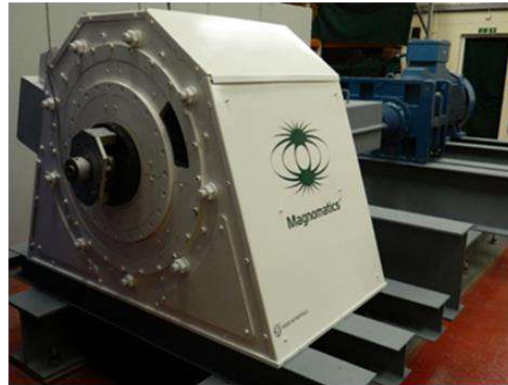


Source BGM Cons

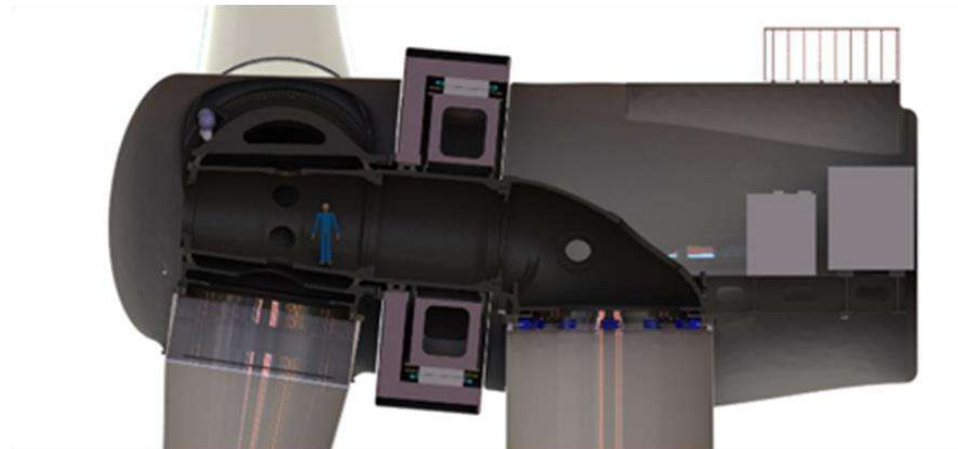


Source Peter Jamieson





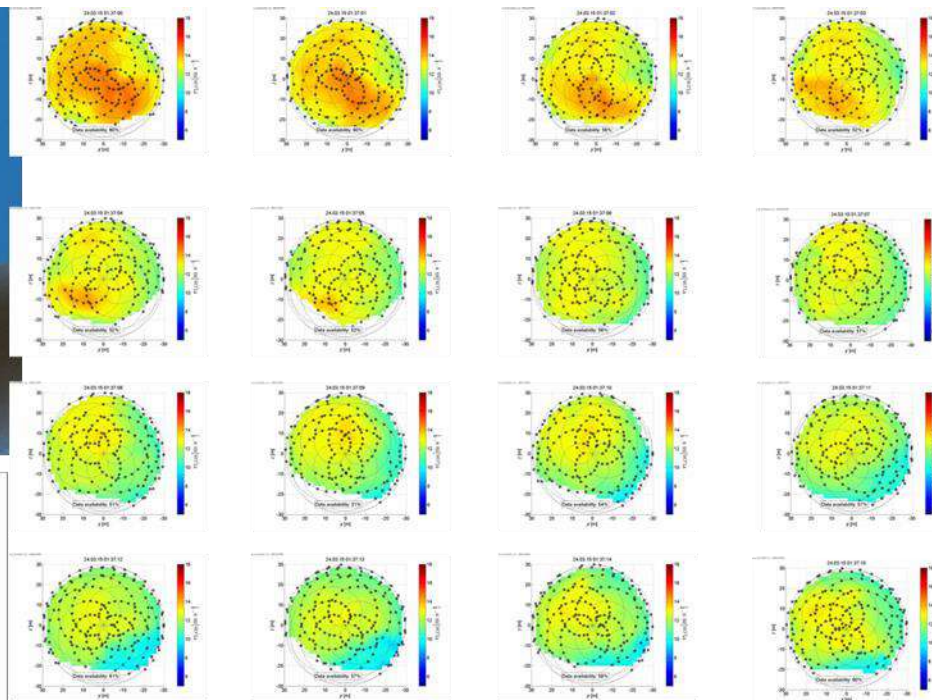
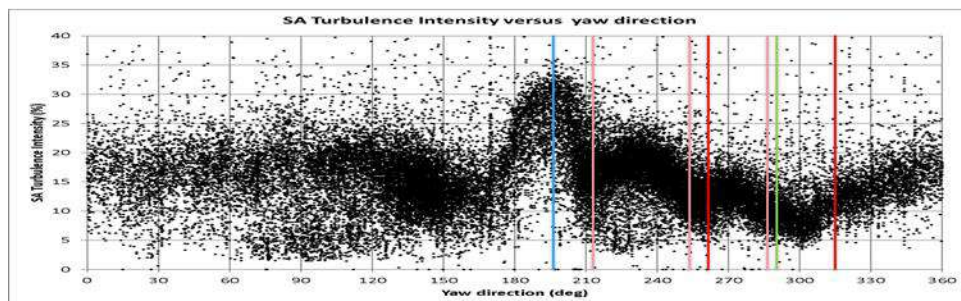
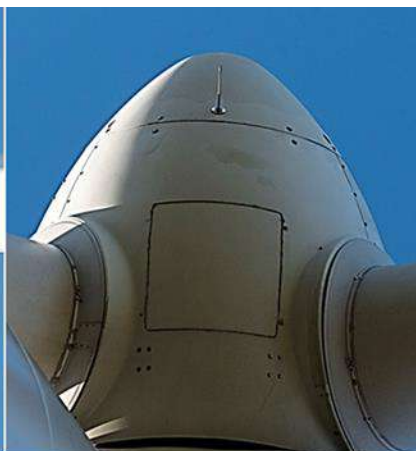
Pseudo-magnetic direct drives (5,16 and 200 kNm demonstrators)



High-temperature Superconducting generators, MgB2 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



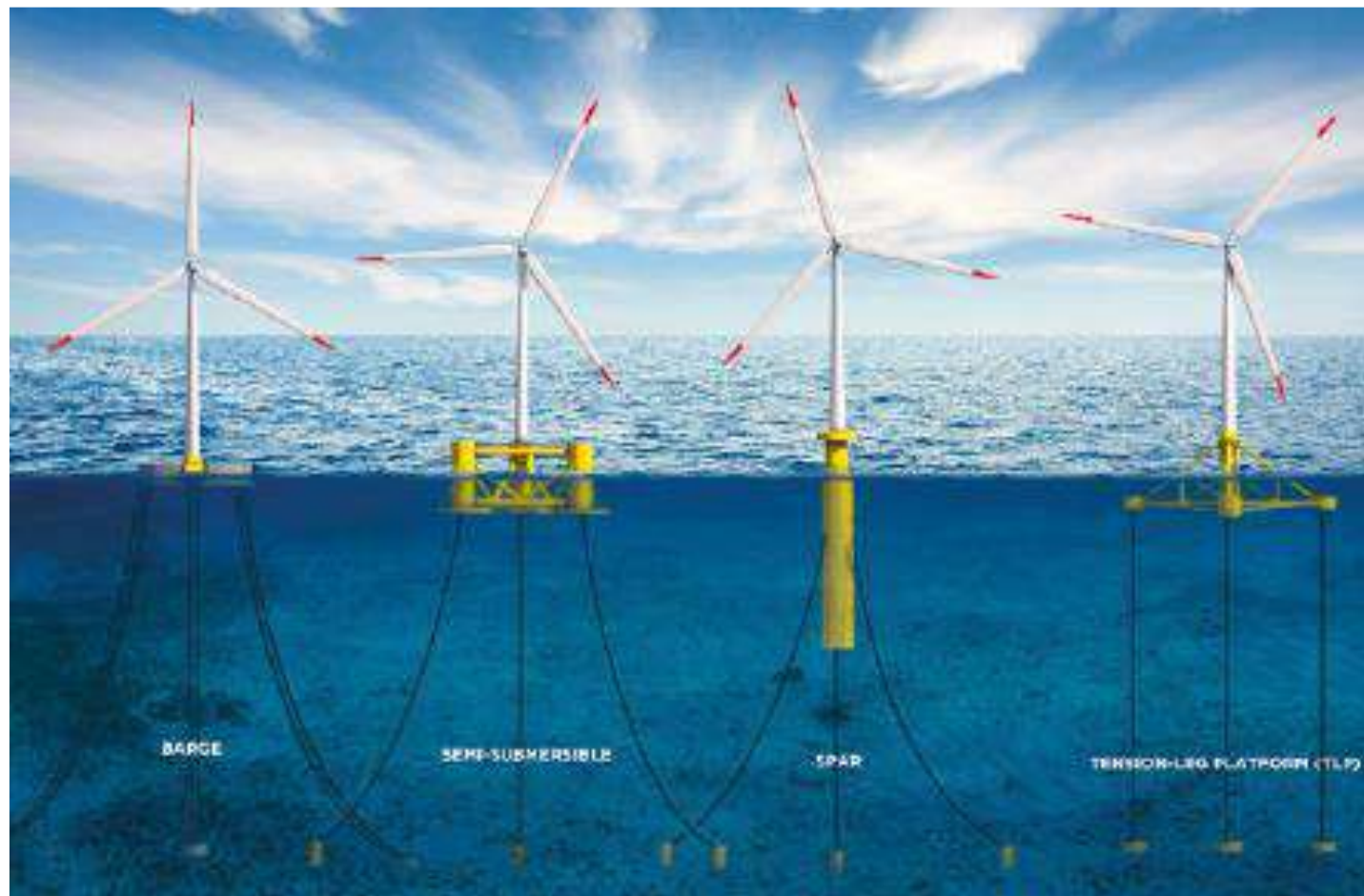
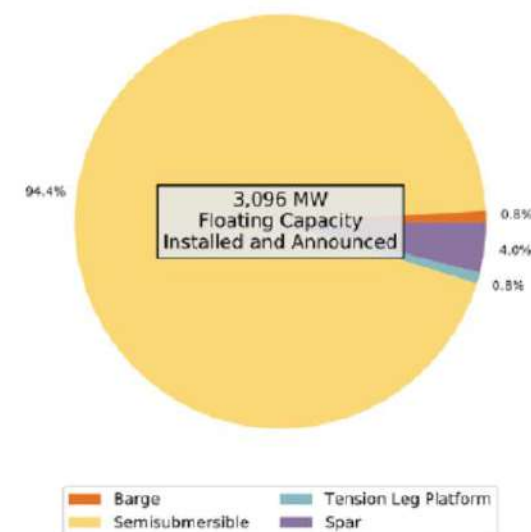


TABLE 2  
Floating offshore wind projects in Europe

| 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



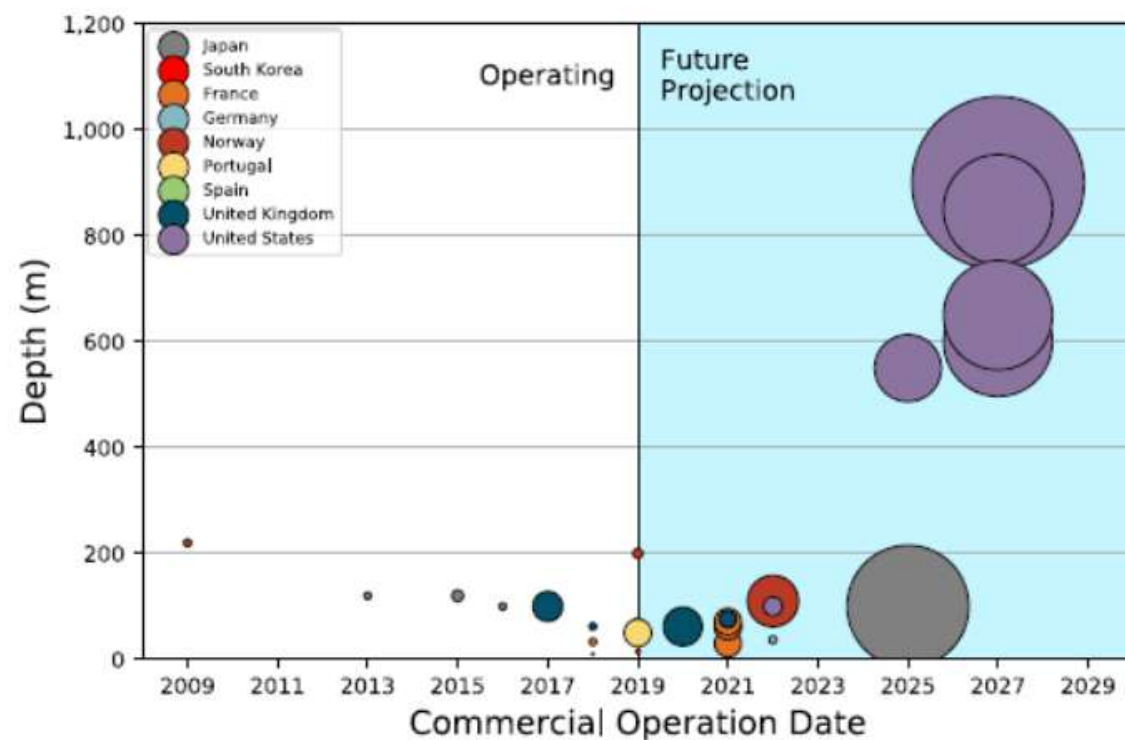


Figure 18. Global floating offshore wind pipeline

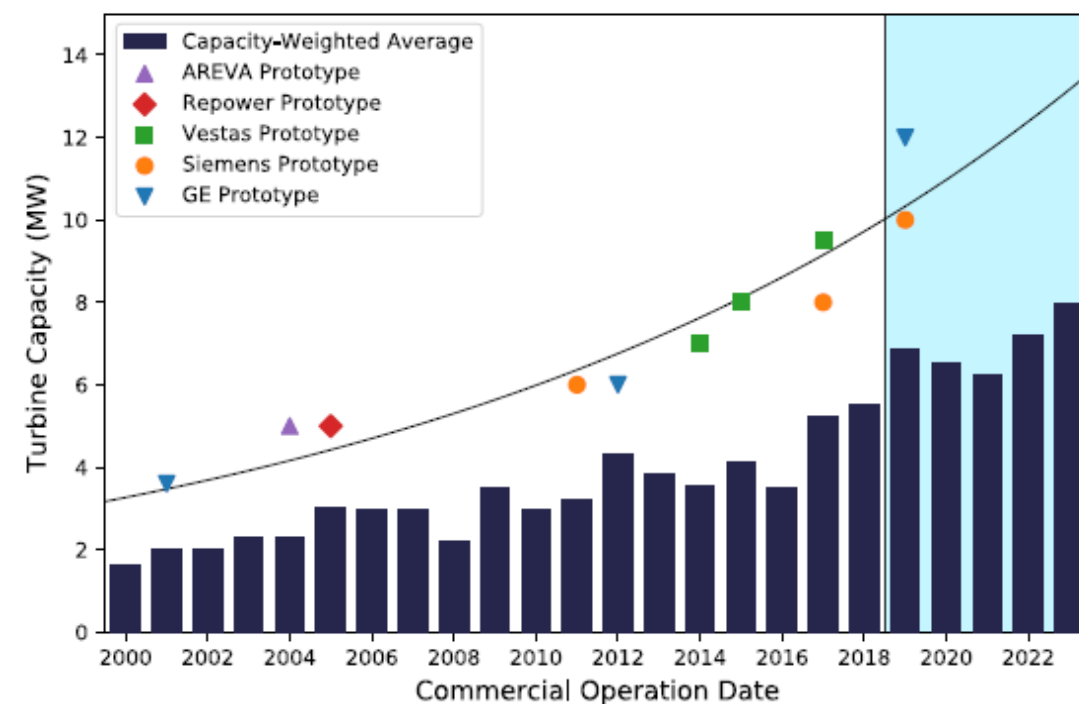
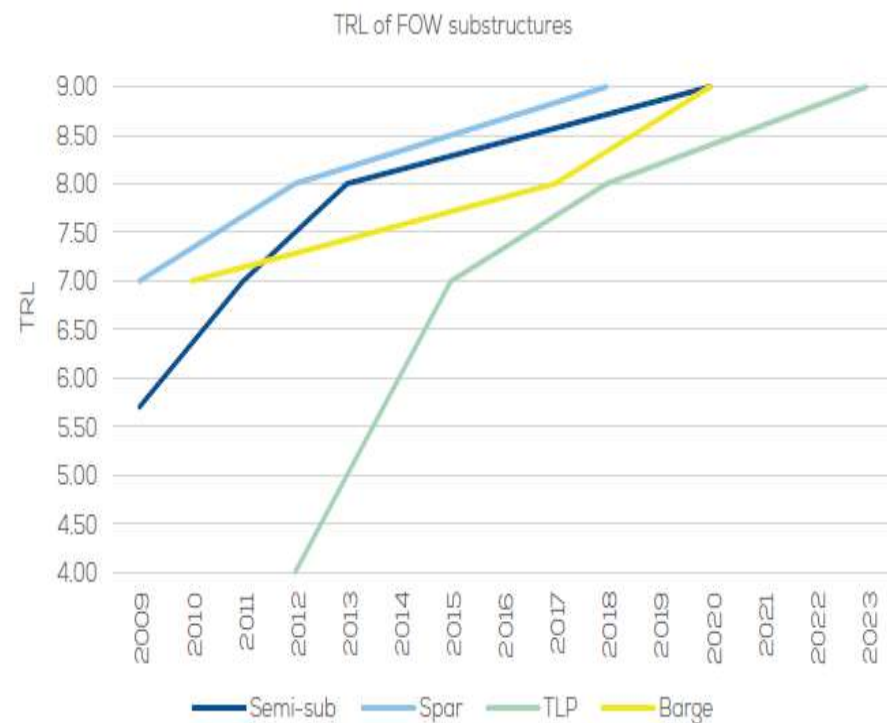


Figure 23. Average commercial offshore wind turbine rating compared to prototype deployment by year

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



FIGURE 1  
Technology Readiness Level of Floating Offshore Wind substructures



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

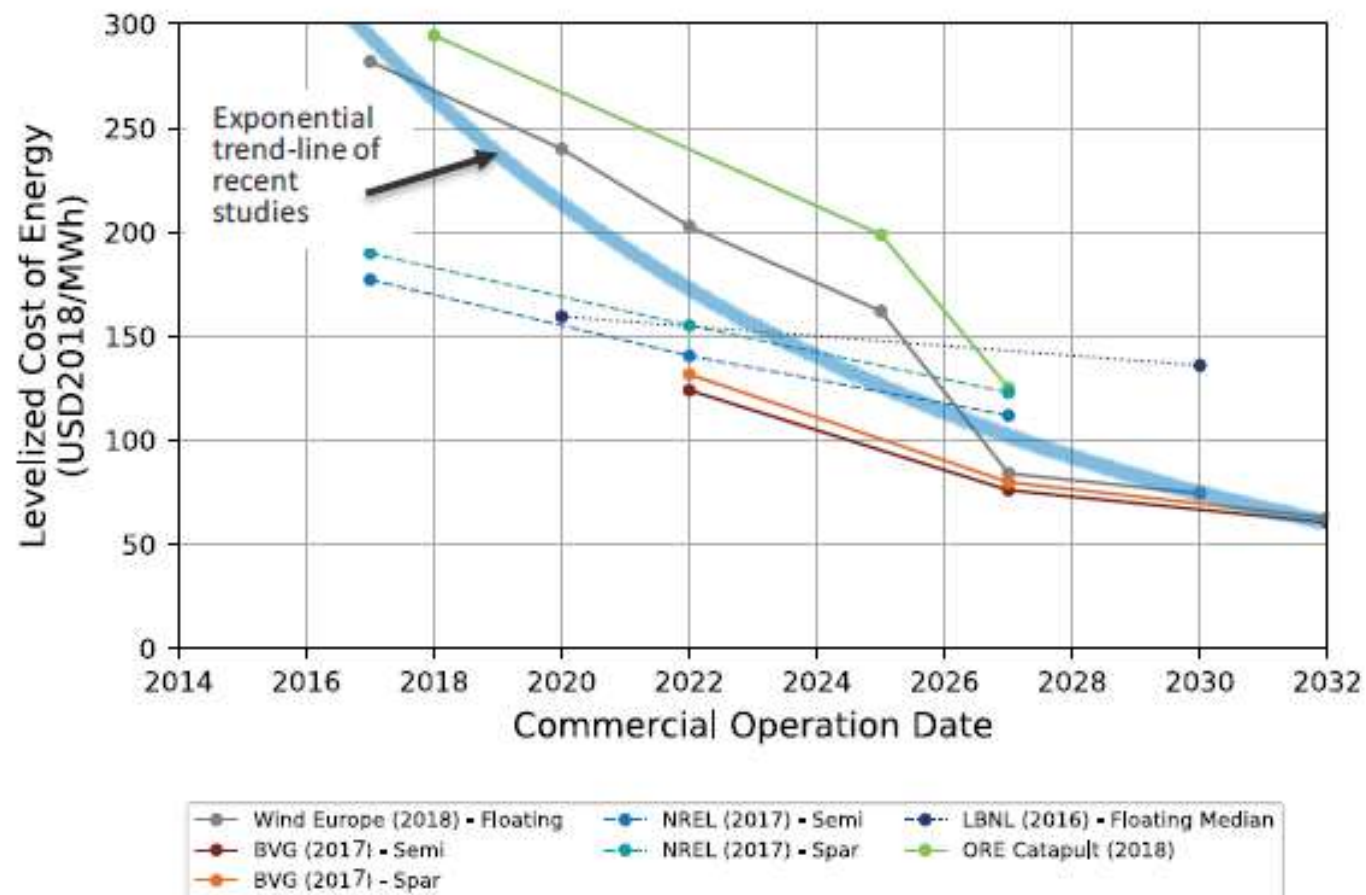


Figure 36. Global LCOE estimates for floating technology<sup>72</sup>

<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**