Globalization of the offshore wind supply chain

After work / ”gå-hjem” meeting

At Center for Logistik og Samarbejde (CLS), Port of Aalborg

Aalborg, November 12, 2018

Presented by Thomas Poulsen, PhD

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My name is Thomas Poulsen

CURRENT EMPLOYMENT

- Independent consultant (2003)
  - Own consulting firm
- Professional board member

EDUCATIONAL BACKGROUND

- PhD, Aalborg University, 2018 – PhD exchange DTU Risø Wind
- MBA, Copenhagen Business School, 2011

WORK BACKGROUND

- Close to 30 years of practical experience
  - Started 1989
- 18 years abroad, 7 countries

EDUCATION:

- PhD
- MBA

COUNTRIES (lived/worked):

- Denmark
- Indonesia
- China
- Singapore
- Hong Kong
- USA
- United Kingdom
- United Arab Emirates

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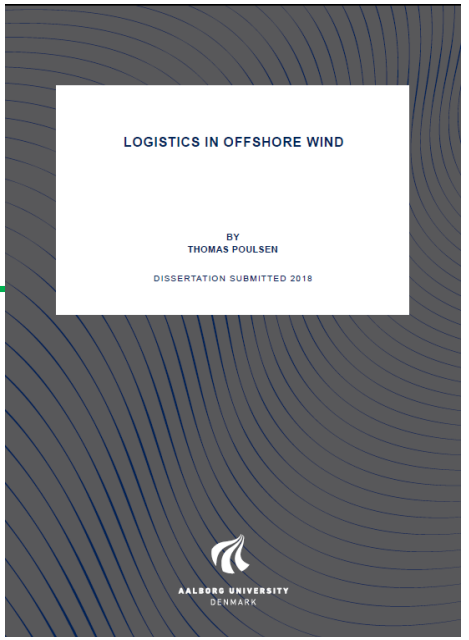
PhD thesis successfully defended

August 21, 2018 at Ørsted



- >100 attendees
- Unanimously recommended to be bestowed with the PhD title
- Assessment committee
  - Associate Professor **Anders Paarup Nielsen**, PhD, Aalborg University (Chair)
  - Principle Engineer/Project Leader **Wei He**, PhD, Equinor
  - Professor **Chris Ellegaard**, PhD, Aarhus University

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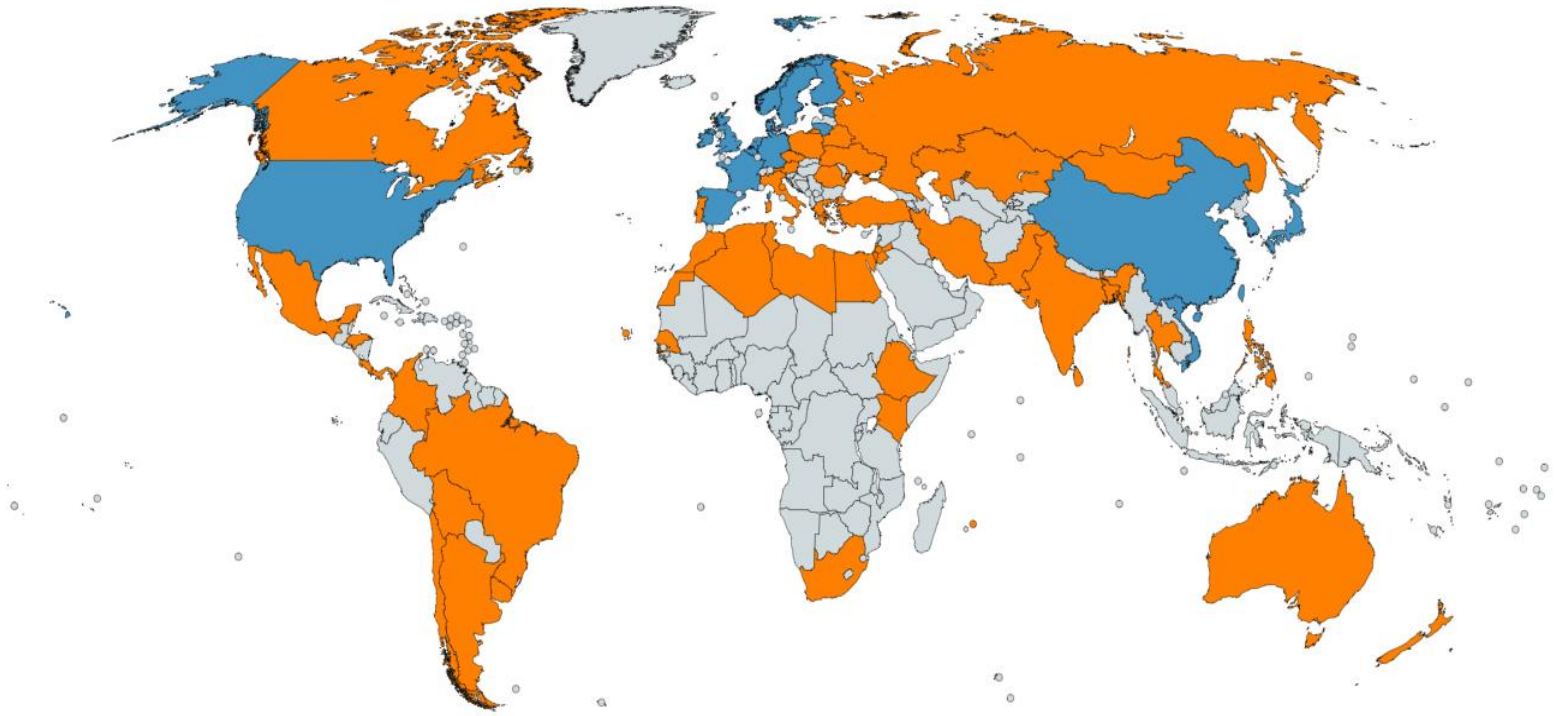
Global wind power | End 2017 cumulative



- 539,123MW installed at end of 2017
  - ➢ 3.5% offshore wind
- Onshore wind
  - – truly global;

    on all continents
- Offshore wind
  - – regional;

    mostly North Europe

Source: GWEC (2018)

Onshore wind – history at a glance…

- Serial production of modern wind turbine generators (WTGs) around 1979
  - Denmark and the USA
- Later on, other markets established a local supply chain
  - Spain and Germany
- Market globalized during 1980s, 1990s, 2000s

Interesting industry?!

- Strong growth

- Industry driven by nations through subsidies; not the market

The emergence of supply chains - globally

- Over time, supply chains emerged
- The wind turbine generator technology is organized as a ”normal” and tiered supply chain system
  - ✓Supply chain lead firms
  - ✓Suppliers
  - ✓Sub-suppliers
- The offshore wind supply chain includes a more complex balance of plant set-up:
  - ✓Cables
  - ✓Foundations
  - ✓Onshore and offshore sub-stations

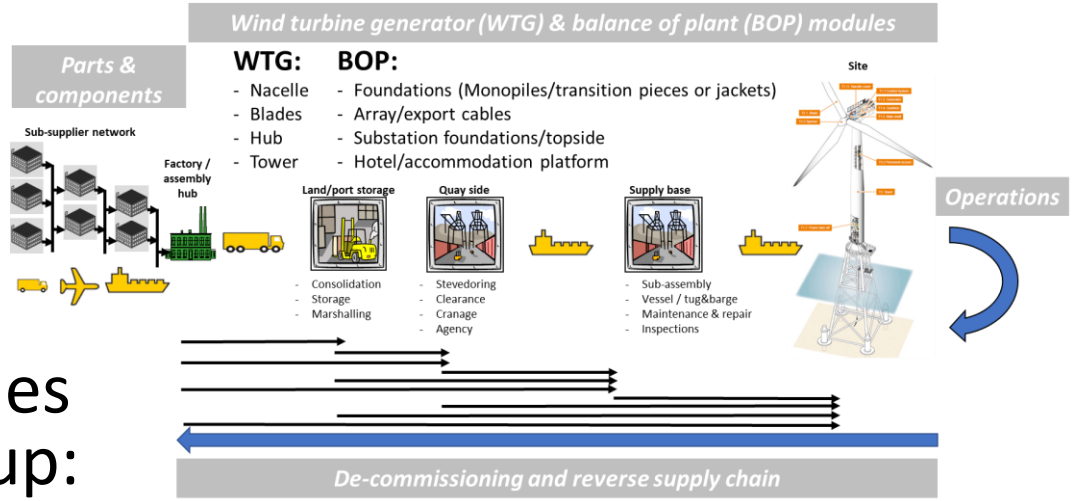


Illustration source: Renewable Energy Solutions

Local content requirements (LCRs) | Onshore

- Prohibited according World Trade Organization rules
- But various market embraced LCRs – implicitly or explicitly
- Key drivers for LCR include:
  - Political support
  - Establishing a local supply chain and possibly cease export opportunities
- Onshore wind examples include China, Brazil and Canada
  - At end of 2017, ranked global first, eighth and ninth, respectively (cumulative installed capacity)
  - LCRs contributed to the emergence of local supply chains
    - China - market size and lower production costs wooed global wind players while regulation requiring local majority ownership in partnerships (joint-ventures) ensuring knowledge transfer and transformation of the country into a major WTG developer and component exporter
    - Brazil - development bank BDNES cheap financing tied to localization enticed global WTG and WTG component OEMs to set up local manufacturing facilities
- LCRs may not necessarily mean competitive production costs

Source: Renewable Energy Solutions analysis

Case study: China | Onshore LCR

Onshore—Installed Capacity (MW)	2000	2005	2010	2015	Growth Factor (2015 over 2000)	CAGR (2005–2015)
China	346	1260	44,781	145,513	420	60.8%
Europe	12,887	40,898	86,619	147,099	10	13.7%
USA	2578	9149	40,298	74,744	28	23.4%
Globally	17,400	59,091	198,065	436,308	24	22.1%
China share in % of globally installed	2.0%	2.1%	22.6%	33.4%	-	-

China onshore LCRs:

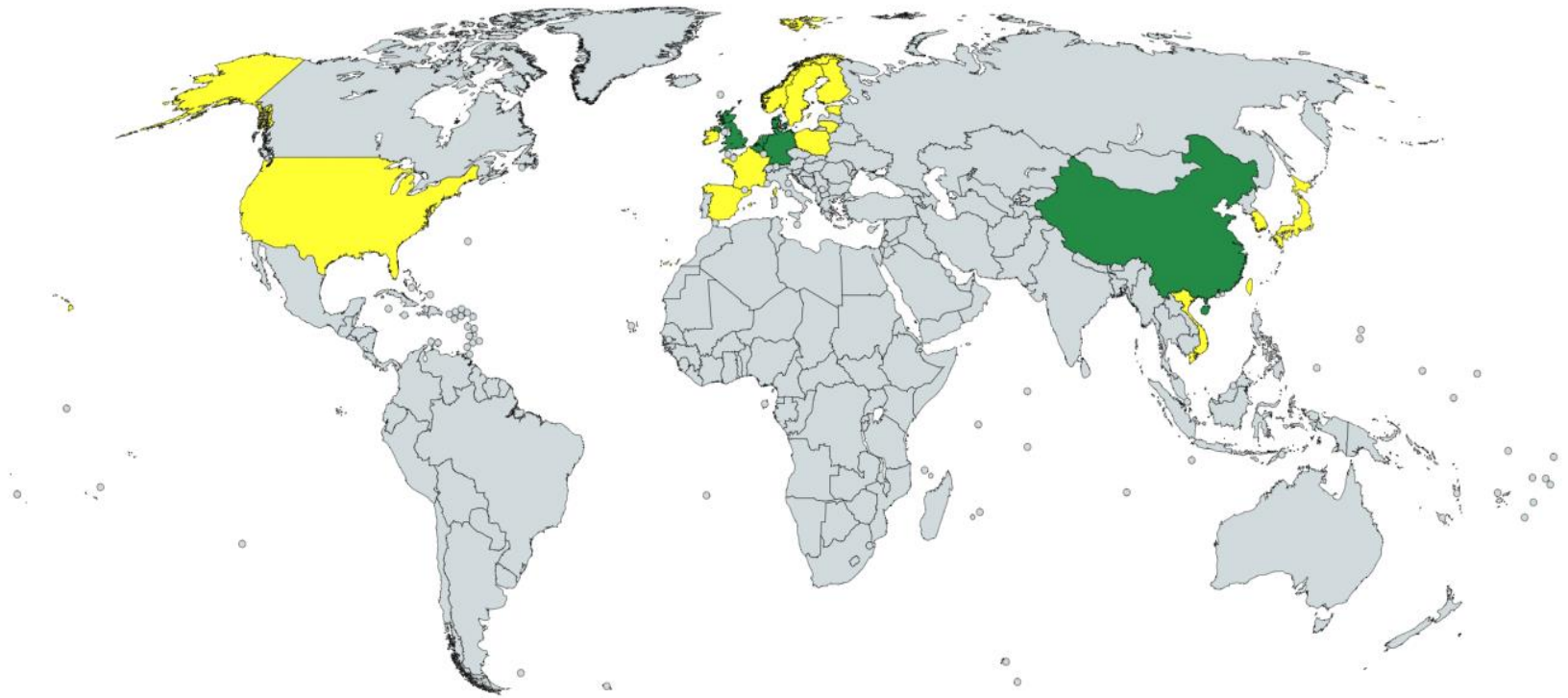
2003	2004	2009
50%	70%	N/A

Market share:

	2006	2013	2014
- Vestas	23.6%	3.2%	
- Gamesa	15.9%	1.6%	
- GE	12.7%	1.1%	
- Number of Chinese WTG OEMs			71 (28)

Source: Poulsen & Hasager, 2017

Global offshore wind | End of 2017 cumulative

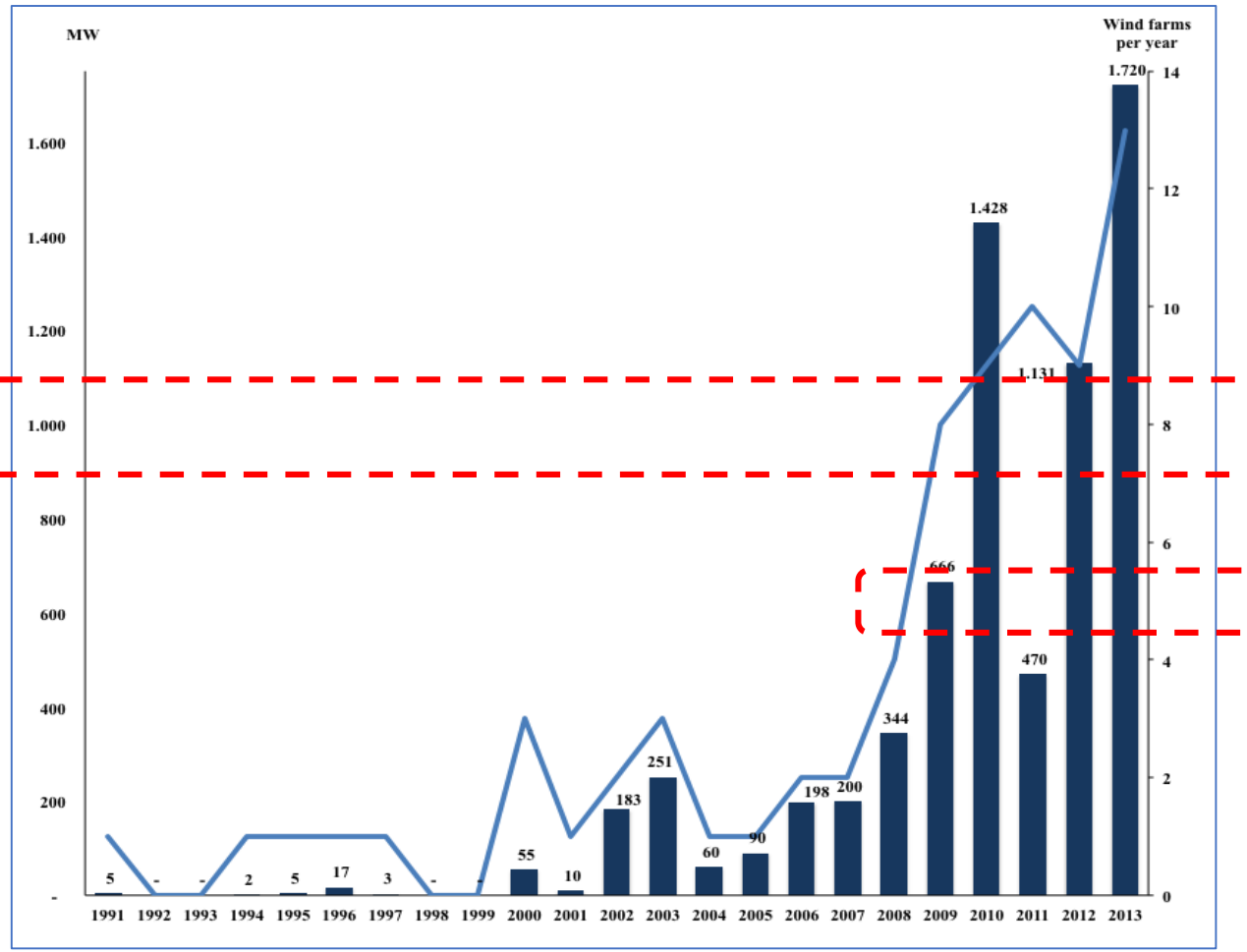


***Note*:** The six markets >500MW installed capacity by end of 2017 are the UK, Germany, Denmark, Holland, Belgium, and China

- Offshore wind on verge of becoming global
- Only six markets* had cumulative capacity exceeding 500MW at end of 2017 (green)
  - Five of these markets are European
- 11 other markets had cumulative capacity below 500MW at end of 2017 (yellow)
  - Majority of projects are demonstration projects
- Six of these are in Europe, four in Asia Pacific, and one in the Americas

Industry maturity: Scale achieved 2008/2009

Annual installed offshore wind capacity globally



1.8 GW

1 GW

500 MW

Installed capacity in MW per year

Number of grid connected offshore wind farms per year

5 offshore wind farms per year

Source: Poulsen, 2015

Global offshore wind | End 2017 cumulative | 18.8 GW installed

Fig. 1 - Country cumulative installed capacity: end of 2008 & 2017

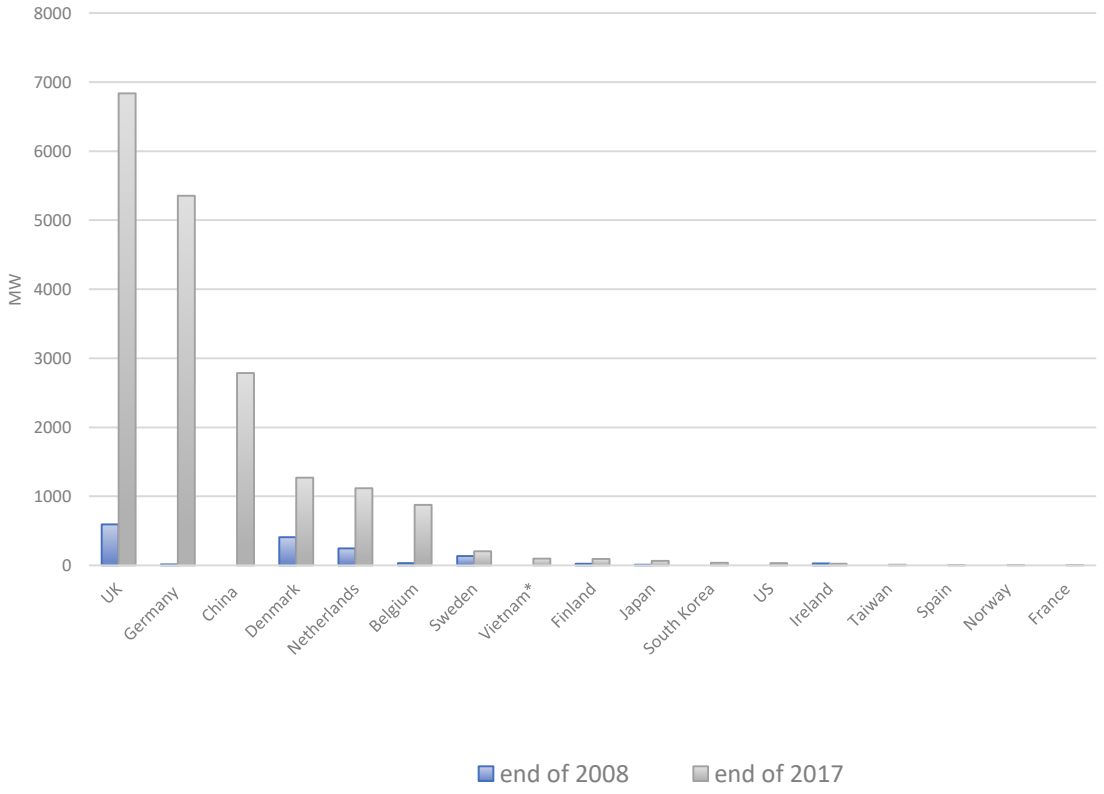
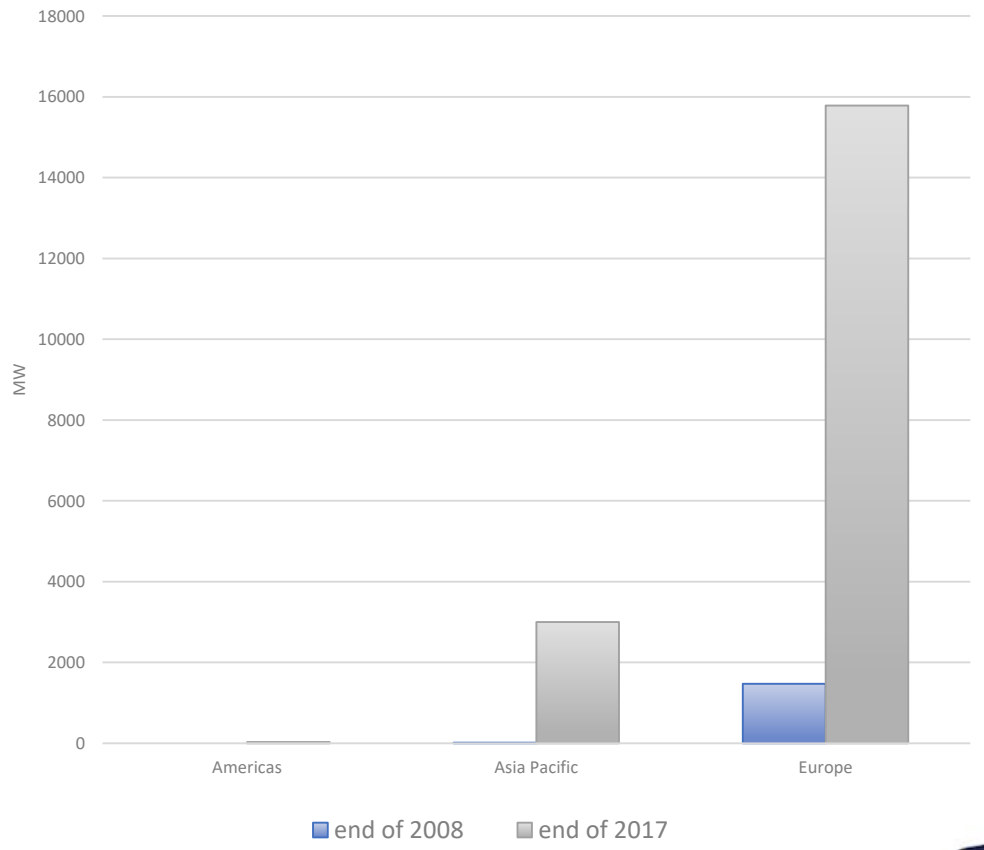
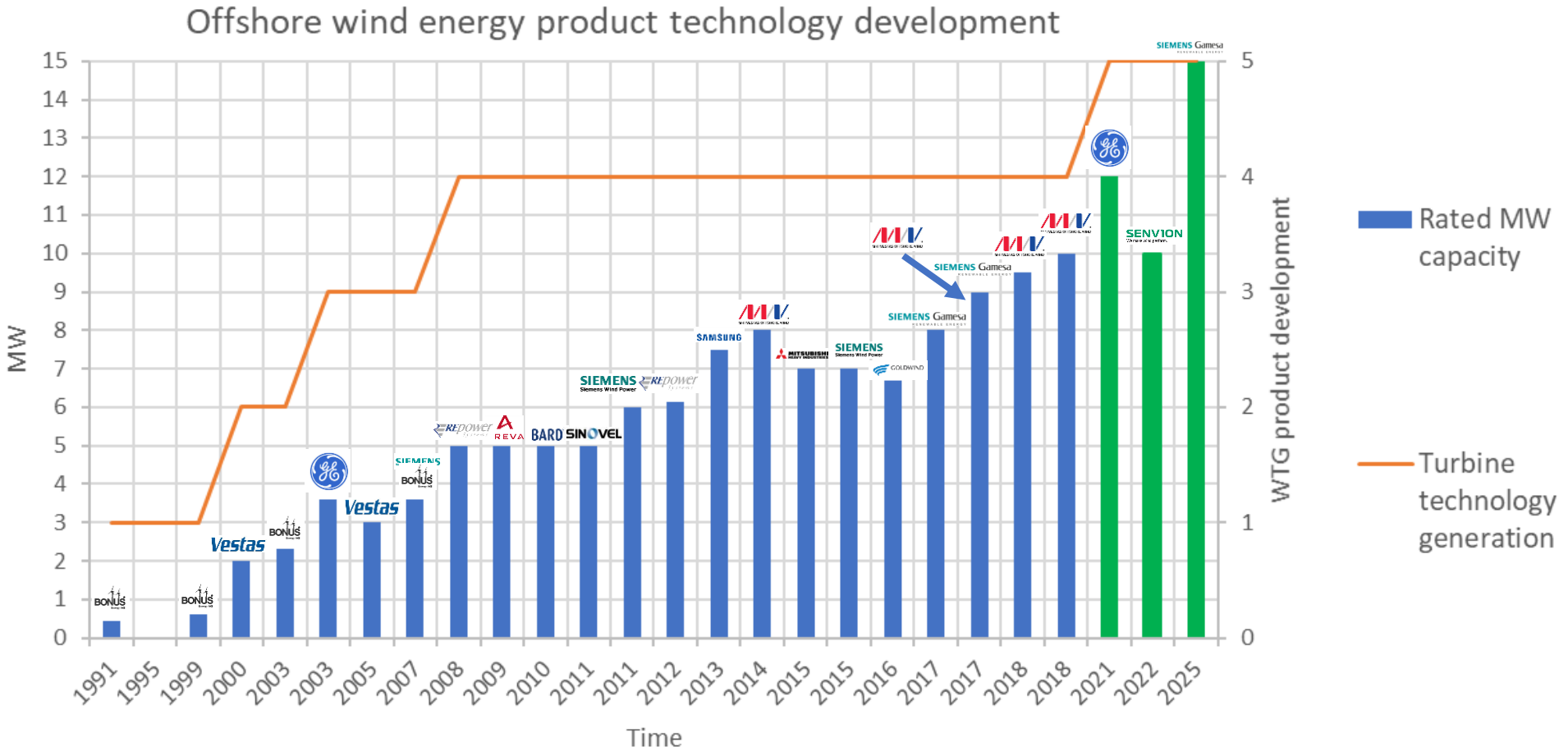


Fig. 2 - Regional cumulative installed capacity: end of 2008 & 2017



Source: Renewable Energy Solutions analysis based on GWEC, IEA Wind and WindEurope data

Turbine output is the driver for logistics innovation



Source: Renewable Energy Solutions analysis

Product life cycles | wind turbine installation vessels

Wind turbine installation vessels:

1st generation – Sea Energy (2002)

2nd gen. – Brave Tern (2014)

3rd gen. – Pacific Osprey (2012)

4th gen. – Seajacks Scylla (2016)

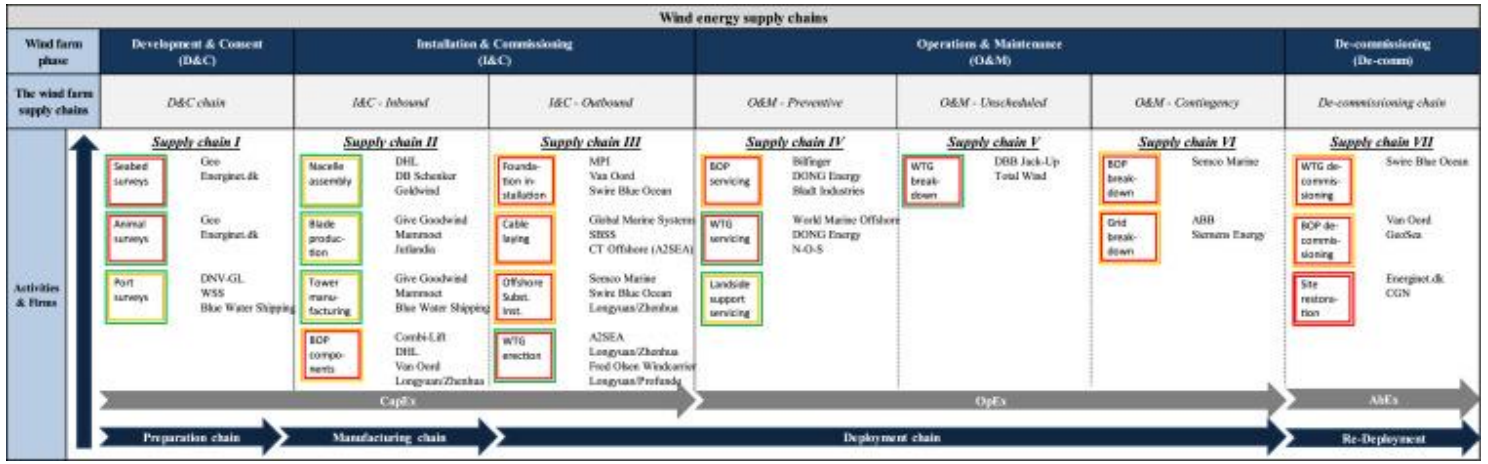
Photos: Courtesy DEME A2Sea, Fred Olsen, Swire Blue Ocean, and Seajacks

Market for installation is at a cross-roads
- what happens now?

- 2022 pipeline with 5th generation WTGs in several markets:
  - Europe
  - Taiwan
  - USA
- Leadtime to design, construct, and test a vessel
- Growth in balance of plant components:
  - Multi-purpose vessels for both WTGs and wind turbine foundations?
  - Separate vessels
  - New innovative solutions to save cost?

Source: Renewable Energy Solutions analysis

Global offshore wind | Wind farm life-cycle | Four key phases



Offshore wind (Poulsen & Lema, 2017):

- Critical logistics elements in all four life-cycle phases
- The costs shift away from WTG (a crucial distinguishing factor between onshore wind and offshore wind)

- An offshore wind farm life-cycle has four key phases (Poulsen, 2015):
  1. Development & consent: 3%
  2. Installation & commissioning (I&C): 55%
     - WTG and WTG components: 24%
     - Balance of plant: 19%
     - Installation & commissioning: 12%
  3. Operations & maintenance (O&M): 38%
  4. De-commissioning: 4%

Local content requirements (LCRs) | Offshore wind

- Offshore wind currently concentrated in Europe (84% at end of 2017) but spreading
  - EU legislation, among other factors, helped diffusion of offshore wind without emphasis on LCR
  - Synergies between offshore wind with existing local industries (e.g., aerospace, automotive, O&G) respective to the OWF lifecycle phase
    - European examples include the Netherlands, Germany, and Belgium
- LCR of WTG assembly is mostly political as well as symbolic since value creation mostly in installation and O&M phase of OWF lifecycle
  - Taiwan – only country with explicit LCRs for offshore wind
    - Taiwan model takes on more gradual LCRs reflecting the offshore wind industry maturation process
  - Individual states within the USA have somewhat "explicit" LCRs – with strong emphasis on local job creation

Source: Renewable Energy Solutions analysis

Global offshore wind | UK | Market overview & LCR

LCR:	Implicit
Offshore wind support scheme	CfD
Cummulative end of 2017:	6836MW
Cummulative end of 2030 (est):	22.5GW
OWF Phase: Development & Consent	Local & other
OWF Phase: Construction |WTG & Components	Yes; offshore WTG OEMs SGRE, MHI Vestas
OWF Phase: Construction |BOP	Local & other European
OWF Phase: Construction |I&C	Local & other European
OWF Phase: O&M	Local & other European
OWF Phase: Decommissioning	
OWF developers:	Local, European, Japanese & Korean

Source: Renewable Energy Solutions analysis

2014 government study

- BVG Associates for the UK Department for Business Innovation and Skills (2014)

No offshore wind supply chain in the UK - industries with useful characteristics:

- Aerospace
- Automotive
- Composites
- Nuclear
- Oil and gas
- Rail

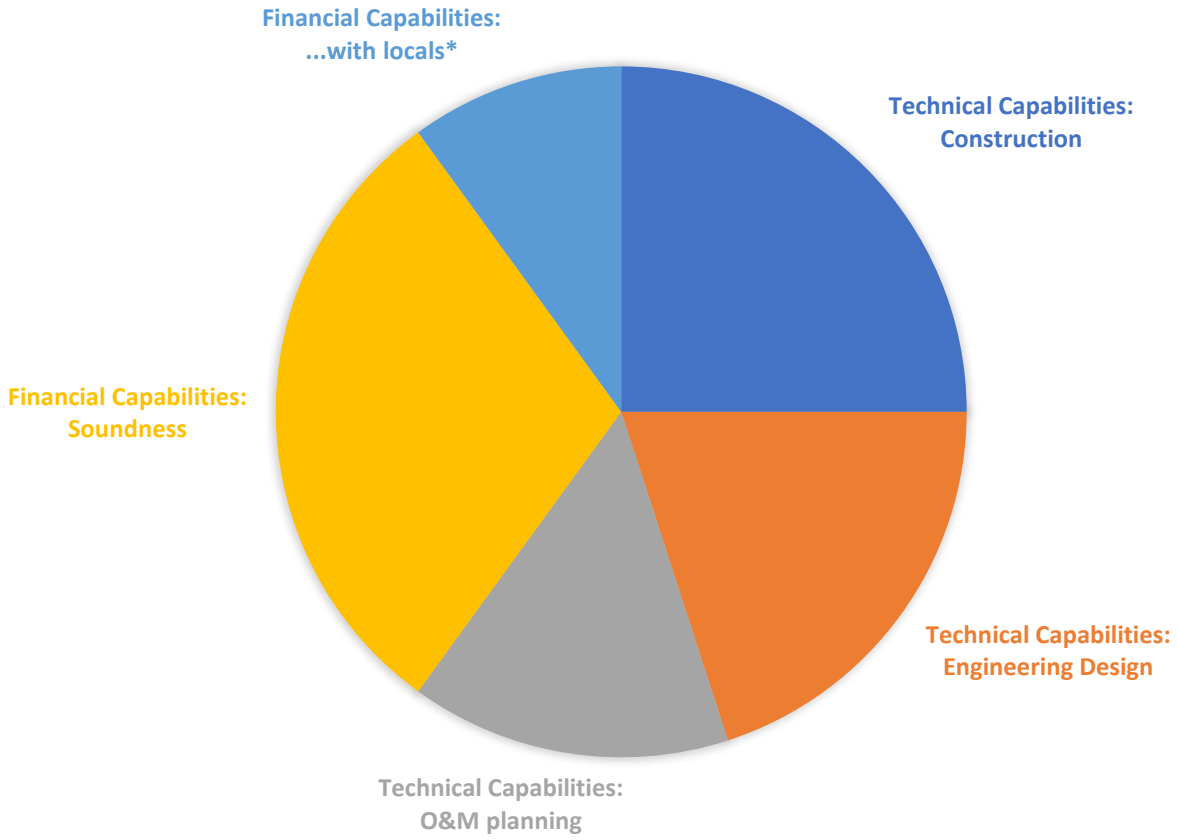
Source: Poulsen & Lema, 2017

Global offshore wind | Taiwan | Market overview & LCR

LCR:	Explicit
Offshore wind support scheme	FIT, auctions
Cummulative end of 2017:	8MW
Cummulative end of 2030 (est):	10GW
OWF Phase: Development & Consent	Partnerships with mostly European firms
OWF Phase: Construction |WTG & Components	Emerging; including MHI Vestas, SGRE, Hitachi
OWF Phase: Construction |BOP	Emerging; Local partnerships with European and some Asian firms
OWF Phase: Construction |I&C	Emerging; Local partnerships with European and some Asian firms
OWF Phase: O&M	Emerging; Local partnerships with European and some Asian firms
OWF Phase: Decommissioning	
OWF developers:	Local, European, Canadian, Australian, Japanese & Singaporean

Source: Renewable Energy Solutions analysis

Global offshore wind | Taiwan | The context for participation



- Between Q3 2017 and Q2 2018, Taiwan:
  - raised its 2025 offshore wind target to 5.5GW
  - approved 10.5 GW planned offshore wind projects
  - awarded 5.5 GW capacity to 10 developers for grid connection by 2025
- In January 2018, MOEA's Bureau of Energy released the **Directions for Allocating Installed Capacity of Offshore Wind Potential Zones**
- Directions stipulated the **Selection Procedure** and the **Auction Procedure**.
- To **take part in the** Selection Procedure, and the subsequent **Auction Procedure**, the OWF developer had to have the capabilities as shown in the pie chart

Source: Renewable Energy Solutions analysis

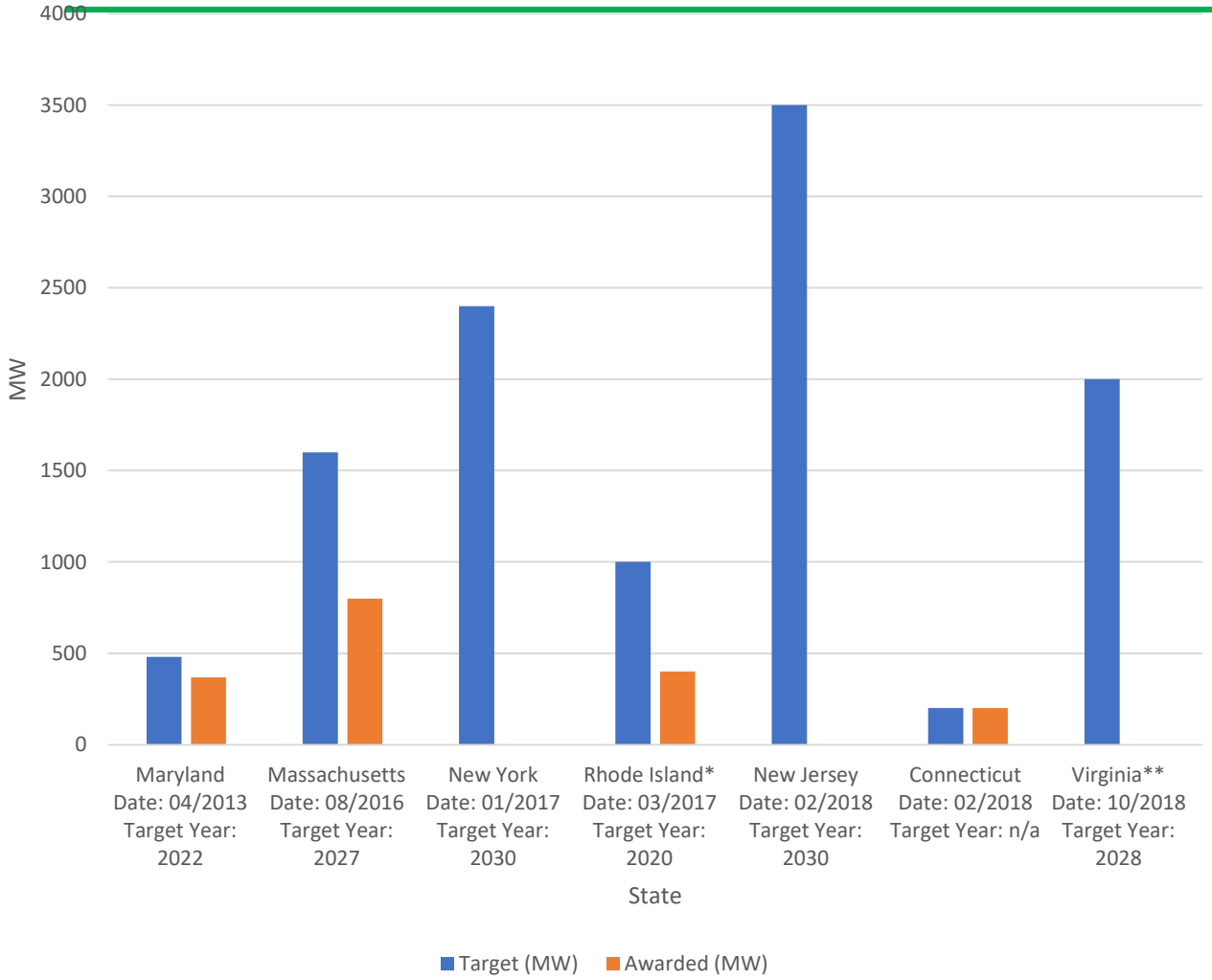
Global offshore wind | Taiwan | LCR

2021-2022	2023	2024-2025
Towers	Towers	Towers
Onshore electrical equipment	Onshore electrical equipment	Onshore electrical equipment
- transformers	- transformers	- transformers
- switches	- switches	- switches
- switchboards	- switchboards	- switchboards
Foundations	Foundations	Foundations
Vessels	Vessels	Vessels
- geological investigation	- geological investigation	- geological investigation
- logistics support	- logistics support	- logistics support
- crew transfer vessels	- crew transfer vessels	- crew transfer vessels
- subsea cable installation	- subsea cable installation	- subsea cable installation
	- turbine & foundation installation	- turbine & foundation installation
	- transport	- transport
	Subsea cables	Subsea cables
	Turbine components	Turbine components
	- transformers	- transformers
	- switchboards	- switchboards
	- power supplies	- power supplies
		Gearbox
		Generator
		Power converters
		Blade
		Nacelle

- Taiwan has no local offshore wind supply chain
- Government plans to position Taiwan as a regional hub for offshore wind
- LCRs have unleashed a flurry of partnerships (joint ventures) at all phases of the OWF farm life cycle
- Foreign offshore wind players, predominantly European, are looking to internationalize
  - Developers face challenges in the short term to find technically and financially (i.e., ability to invest in new facilities or facility upgrades) local suitors
- ***So, what's next?***

Source: Renewable Energy Solutions analysis

Global offshore wind | USA | Offshore wind development



- Market volume and geography facilitated development of local onshore wind supply chain without emphasis on LCR
- Neither a national official offshore wind target nor national LCR for offshore wind
- Individual states announced offshore wind targets (renewable energy)
  - 2013 – 1 state
  - 2016 – 1 state
  - 2017 – 2 states
  - 2018 – 3 states
- State-level key drivers for offshore wind development include: Job creation
- Nearly 2GW capacity has been awarded in four states with non-US developers taking the lead

Source: Renewable Energy Solutions analysis

Global offshore wind | China | Market overview & LCR

LCR:	Implicit
Offshore wind support scheme	FIT, but to transition to auctions
Cummulative end of 2017:	2788MW
Cummulative end of 2030 (est):	40GW
OWF Phase: Development & Consent	Mostly local, increasingly courting Europeans
OWF Phase: Construction |WTG & Components	Yes; 10 local OEM WTGs
OWF Phase: Construction |BOP	Local
OWF Phase: Construction |I&C	Local
OWF Phase: O&M	Local
OWF Phase: Decommissioning	
OWF developers:	Local

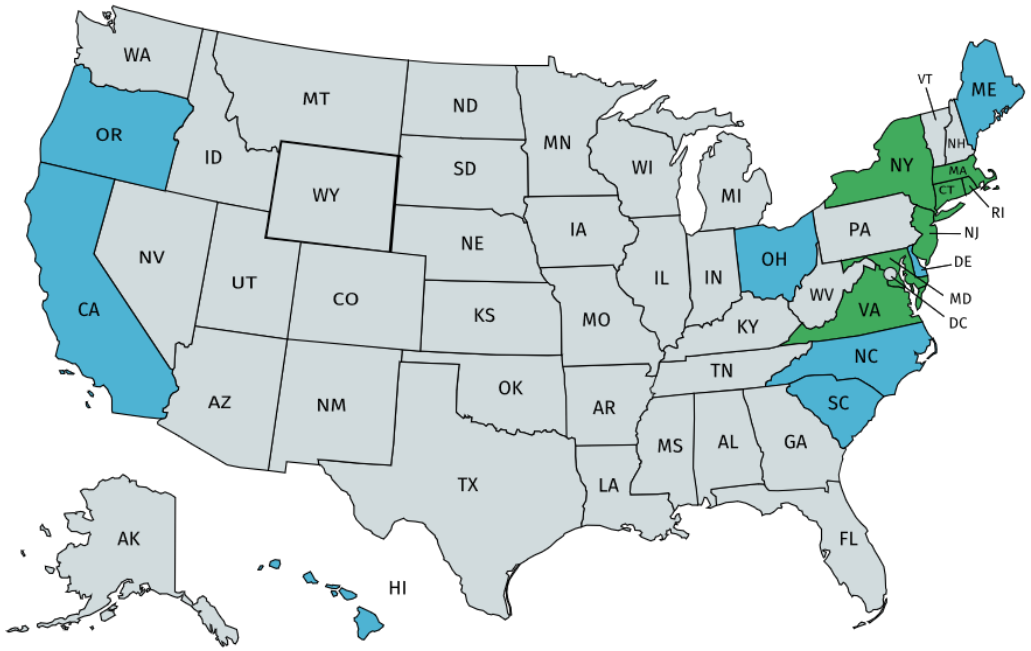
Source: Renewable Energy Solutions analysis

Global offshore wind | USA | LCR

LCR:	Explicit*
Offshore wind support scheme	ITC; to expire after 2019; could be extended following outcome of Nov.2018 mid-terms
Cummulative end of 2017:	30MW
Cummulative end of 2030 (est):	13GW
OWF Phase: Development & Consent	Partnerships with European firms
OWF Phase: Construction |WTG & Components	Potential; hosts onshore facilities for the top offshore WTG OEMs (SGRE, MHI Vestas*, GE)
OWF Phase: Construction |BOP	Potential; O&G plus likely European partnerships
OWF Phase: Construction |I&C	Potential; O&G plus likely European partnerships
OWF Phase: O&M	
OWF Phase: Decommissioning	
OWF developers:	Local but predominantly European

Source: Renewable Energy Solutions analysis

Global offshore wind | USA | LCR |



Shipping and logistics:

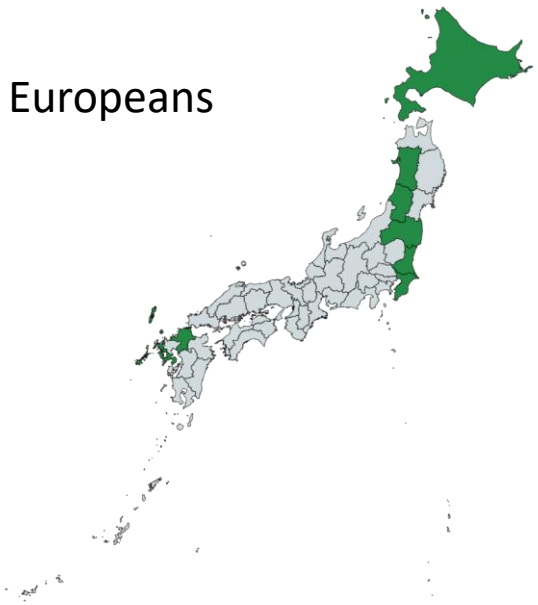
- Merchant Marine Act of 1920 (the Jones Act)

- Emphasis from state authorities to create jobs "forcing" developers to commit to localisation of supply chain
  - MA: **Vineyard Wind** announced plans to build an O&M facility at Vineyard Haven (April 2018)
  - RI: **Deepwater Wind** (now Ørsted USA) announced port-facility upgrades in Providence and Quonset Point (May 2018)
  - CT: **Deepwater Wind** (now Ørsted USA) committed to using the Port of New London, including:
    - Up to USD 15 million upgrades to the New London State Pier;
    - Use of New London as a construction/assembly base for foundation components and OSS;
    - Contracting a Connecticut-based boat builder to construct one of the project's CTVs
  - MD: **US Wind** (268 MW OWF project) plans to run O&M out of Ocean City, with a laydown and handling facility at Tradepoint Atlantic in Baltimore.
  - MD: **Deepwater Wind** (now Ørsted USA) (120 MW Skipjack project) is investing in steelworks and port facilities in the Greater Baltimore area

Source: Renewable Energy Solutions analysis

Global offshore wind | Japan | Market overview & LCR

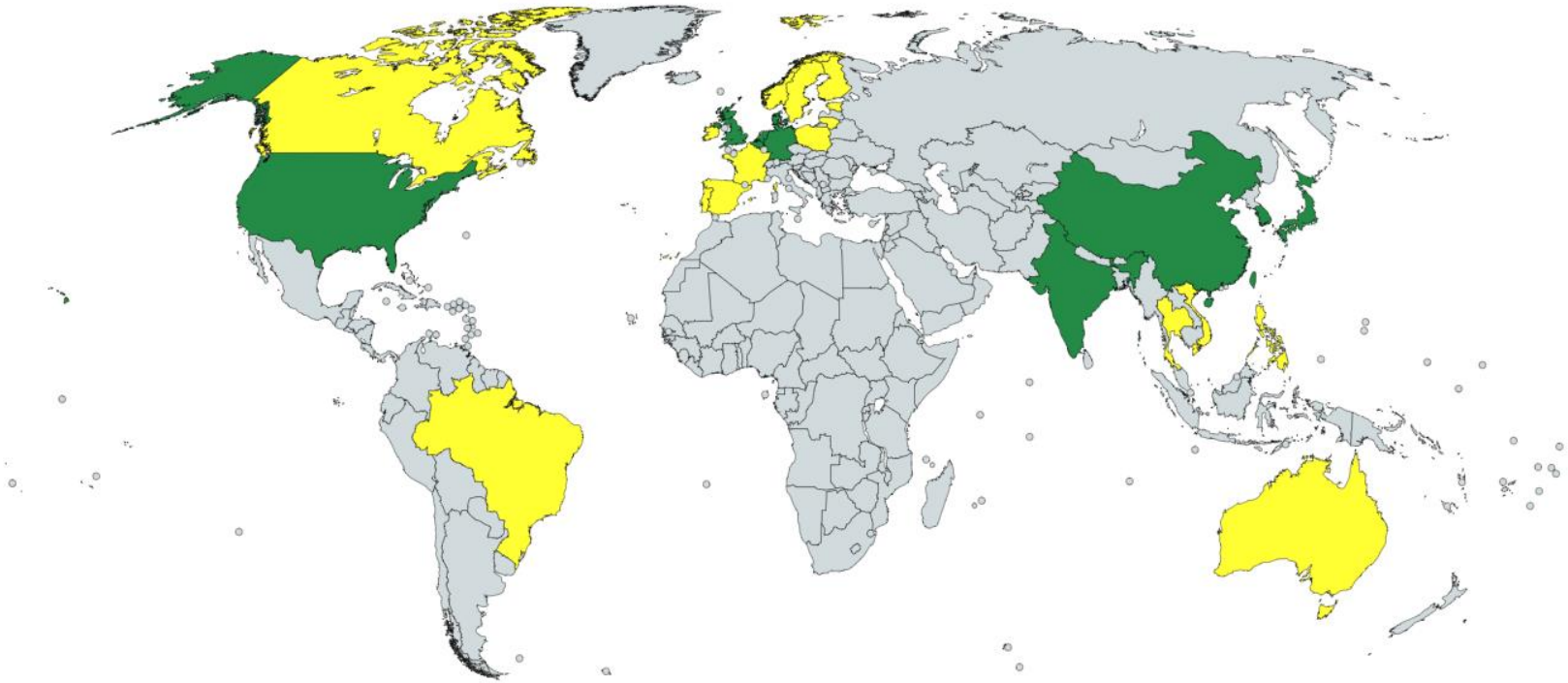
LCR:	Implicit
Offshore wind support scheme	FIT, but to transition to auctions
Cummulative end of 2017:	2788MW
Cummulative end of 2030 (est):	40GW
OWF Phase: Development & Consent	Mostly local, increasingly courting Europeans
OWF Phase: Construction | WTG & Components	Yes; 10 local OEM WTGs
OWF Phase: Construction | BOP	Local
OWF Phase: Construction | I&C	Local
OWF Phase: O&M	Local
OWF Phase: Decommissioning	
OWF developers:	Local



Source: Renewable Energy Solutions analysis

Global offshore wind | 2030 est. | 130GW new capacity

- market of strong growth



- At least two regional supply chain hubs to emerge in Asia Pacific and the Americas
- Regional economic agreements, e.g. ASEAN in South East Asia, to facilitate OWF lifecycle phase specialized supply chain development in member countries
- European players, due to first mover advantage, to play key role in shaping policy in most markets outside Europe

- Offshore wind to significantly spread beyond Europe in the next decade
- Markets with cumulative installed offshore capacity exceeding 4GW at end of 2030 estimated to be 11
  - Six in Europe, Four in Asia Pacific, and one in the Americas (green)
- Asia Pacific expected to overtake Europe
  - Global share at end of 2020 estimated to triple from 2017 levels

Source: Renewable Energy Solutions analysis

Conclusion
- and proposed discussion topics

- Beginning of the meeting: Example from North Jutland area of Denmark
  - ✓Local supply chain
  - ✓Test sites and developed infrastructure/assets
  - ✓Skilled work force with educational support from university
- This presentation: Globalization and market making internationally
- Proposed discussion topics:
  - ➢Infusion of knowledge/talent into new markets that may require local content
  - ➢Opportunities for a local supply chain to regionalize and go global
  - ➢Possible benefits for a Danish founded supply chain as markets emerge
  - ➢Experiences with logistics from emerging markets with focus on local content
  - ➢Opportunities to help drive cost reductions globally

Thank you for your attention!

Questions and answers

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- The information contained herein has been prepared by Thomas Poulsen
- Thomas Poulsen has completed his work at Aalborg University and fully owns the rights for the information contained in this presentation, his publications, and the www.windscm.com website
- Thomas Poulsen now works for his own company, Renewable Energy Solutions

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