RESEARCH UPDATE - LOOKING AHEAD

PREPARED BY THOMAS POULSEN

FOR THE

ENERGY & TRANSPORT SUMMIT III

CBS Executive
Frederiksberg, Denmark
December 3, 2018

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MY NAME IS THOMAS POULSEN

WHAT I DO

EDUCATIONAL FOCUS LATE IN LIFE – OVER THE PAST 10 YEARS

- **PhD** from Aalborg University – PhD exchange at DTU Risø Department of Wind Energy
- **MBA** from Copenhagen Business School – Shipping and Logistics, the Blue MBA
- *Leadership, General Management, Interim management, Project management, Training*

INDEPENDENT CONSULTANT

- **Current position:** Managing Partner at Panticon
- **Industry Expertise:** Retail, Consumer, Automotive, Chemicals, Manufacturing, Energy, Transportation, and Offshore
- **Focus:** Strategic Management Advisory, Mergers & Acquisitions, and Market Analysis

NON-EXECUTIVE MEMBER OF SELECT SUPERVISORRY BOARDS

- Long-term Support to Management Teams



EXPERIENCE

Tenure of 30 years with five employers

Lived and worked for 18 years in seven countries outside native Denmark:

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

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OBJECTIVE

A brief look at the past

- PhD Research project
- 2012 – 2018
- Milestones



AALBORG UNIVERSITY
DENMARK

DTU Technical University of Denmark

DEN DANSKE MARITIME FOND

Looking ahead

- A glimpse of the future
- Rooted in the present
- Based on the research findings

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A BRIEF LOOK AT THE PAST

PhD Research Project

2012 – 2018

Milestones

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PHD DEFENSE AUGUST 21, 2018

Hosted in Gentofte by 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 Ms **Wei He**, PhD, Equinor
  - Professor **Chris Ellegaard**, PhD, Aarhus University

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INDUSTRY RELEVANCE

Reference Group



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9 REFERENCE GROUP MEETINGS

Downloads and information available on www.windscm.com

	Date	Hosting organization	City in Denmark	After work / 'gå-hjem'
1	August 28, 2013	Aalborg University	Copenhagen	No
2	March 20, 2014	Ørsted	Gentofte	Yes (40)
3	September 2, 2014	Offshoreenergy.dk	Esbjerg	Yes (60)
4	March 17, 2015	Per Aarsleff A/S	Hvidovre	Yes (35)
5	September 2, 2015	Siemens Gamesa Renewable Energy	Brande	Yes (40)
6	March 9, 2016	Port of Esbjerg	Esbjerg	Yes (50)
7	August 24, 2016	Danish Shipping	Copenhagen	Yes (60)
8	March 29, 2017	DHL Global Forwarding Industrial Projects	Copenhagen	Yes (50)
9	November 12, 2018	House of Energy	Aalborg	Yes (30) ***(375 est.)***

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INPUT PROVIDED BY REFERENCE GROUP TO PHD

#1	Purpose, charter, inauguration
#2	Current challenges (shipping/logistics)
#3	Relevance of academic plan
#4	Offshore wind trends (Danish context)
#5	Turbine and foundation types/sizes
#6	O&M (tour of firms)
#7	O&M strategies, logistics, and firms
#8	Supply chain readiness (different angles)
#9	Looking back and looking ahead

Downloads and information available on www.windscm.com

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8 AFTER-WORK / GÅ-HJEM MEETINGS

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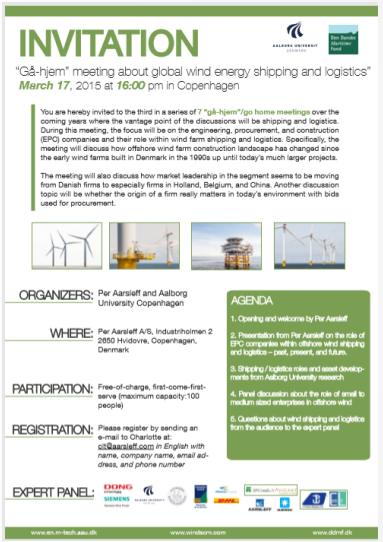

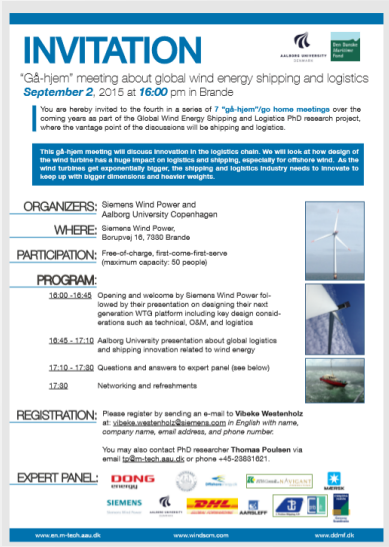

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3 MAJOR CONFERENCES

ENERGY & TRANSPORT SUMMIT I

- October 10, 2014 – 3 panels, 10 speakers
- Linked to Danish Maritime Days
- PhD Research Project opening conference

ENERGY & TRANSPORT SUMMIT II

- October 9, 2015 – 3 sections, 5 speakers
- Linked to Danish Maritime Days
- PhD Research Project mid-term conference

~300 participants

www.energytransportsummit.com

#energytransportsummit



ENERGY & TRANSPORT SUMMIT III

Today!

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WHAT IT TAKES

2009 – 2011:

Copenhagen Business School – The Blue MBA in Shipping and Logsitics
The gap was discovered
- academia
- industry thought leadership across life-cycle phases

2012 – 2013:

Funding application DDMF
Partnership with AAU
- upgrade of Master ECTS

2014 –

PhD research project
- planning
- set-up at AAU with supervisors etc.
- understand AAU (wind, logistics, social science)
- teaching/supervision
- training (doctoral level ECTS)
- data collection
- analysis
- PhD exchange at DTU Risø
- paper writing, peer reviews, revisions, and publication
- academic and industry conferences
- project Reference Group and project conferences
- PhD thesis, review, revision, review, defense and publication

– 2018

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BY THE NUMBERS

Peer-reviewed / defended PhD thesis

- ✓8 peer-reviewed and published *academic journal articles*
- ✓450 semi-structured PhD related *interviews*
- ✓38 formal PhD related *interviews*
- ✓*Survey* to 115 PhD related respondents
- ✓140 PhD related participant observation *site visits*
- ✓*Keynote speaker* at 18 conferences
- ✓*Press* coverage (written 38x, TV 1x)

Peer-reviewed / graded master thesis

- ✓8 peer-reviewed and graded MBA *module assignments*
- ✓99 semi-structured master thesis related *interviews*
- ✓25 master thesis participant observation *site visits*

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STAYING RELEVANT THROUGHOUT

ACADEMIA

MBA

PhD

INDUSTRY

Consulting firm

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LOOKING AHEAD

A glimpse of the future

Rooted in the present

Based on the research findings

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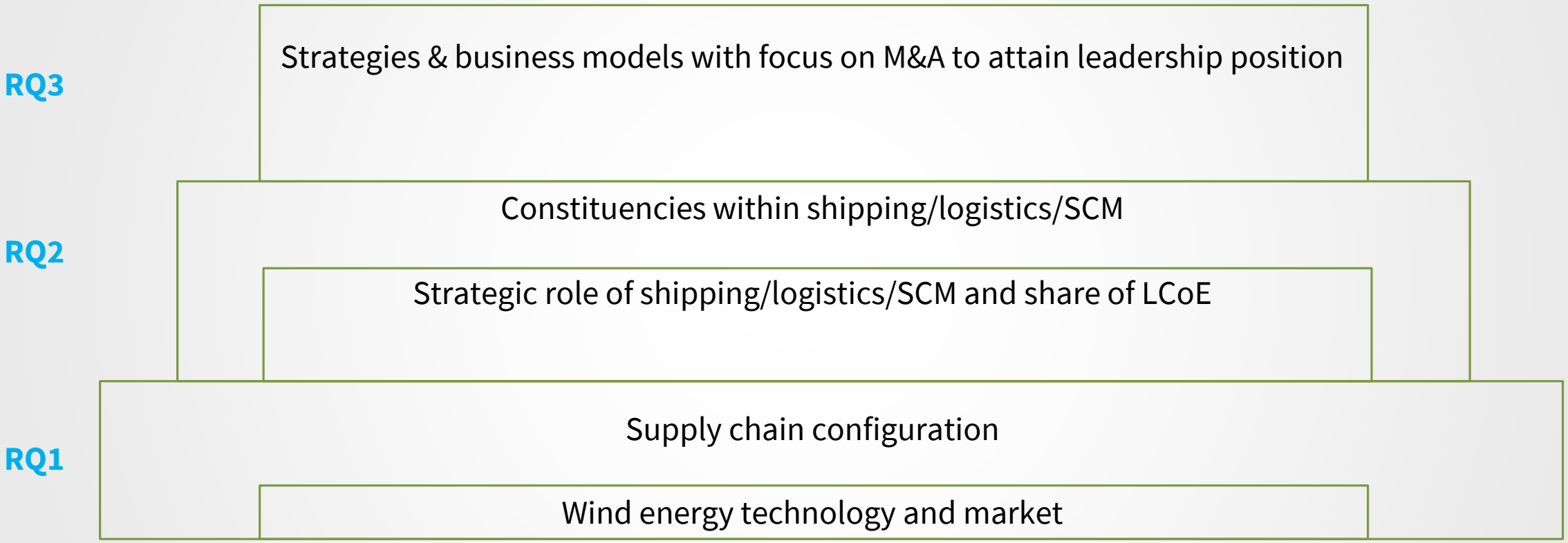
TIERED PHD PROJECT RESEARCH QUESTIONS



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RESEARCH PROJECT AND PHD THESIS - GOALS

- How do developments in product technology, wind farm life-cycle phases, and market features of the wind energy industry relate to the configuration of the associated wind energy supply chains?
- How do shipping, logistics, and SCM activities support wind energy supply chains and what is the shipping/logistics/SCM share of end-to-end LCoE?
- How may strategic management planning and implementation efforts enable a leadership position, especially with the use of M&A, for firms in the shipping, logistics, and SCM business serving the wind energy industry nationally, regionally, and/or globally?

Publications

1. How is offshore wind ***organized*** in terms of logistics, and is logistics of ***importance***?
2. What are the offshore wind logistics ***costs***?
3. As the offshore wind industry ***globalizes***, what characterizes logistics in established markets compared to emerging markets?

Thesis

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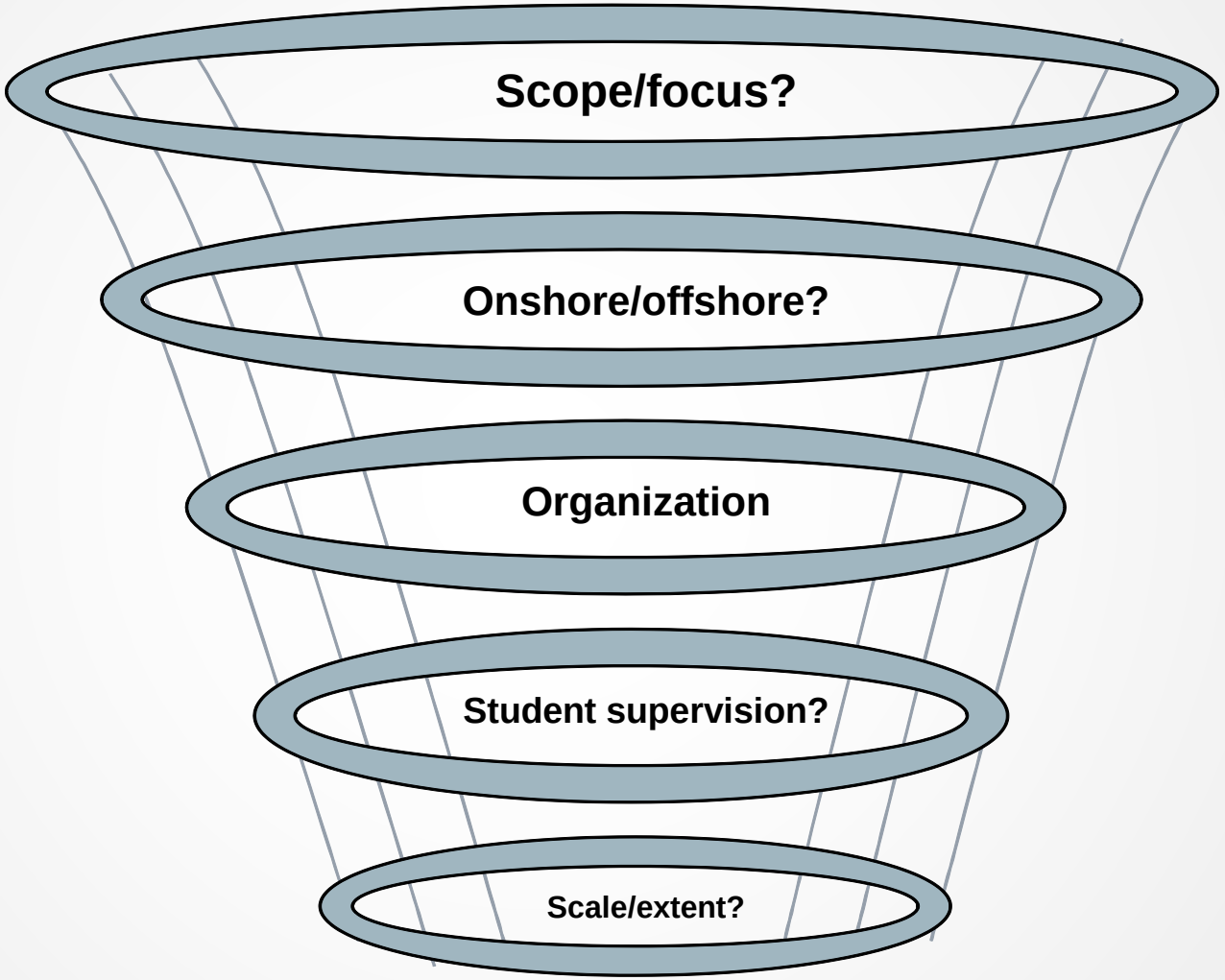
FUNNEL FOR CASE STUDY SELECTION





Source: Poulsen, 2018

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CHOSEN CASE STUDIES – MATCH WITH GOALS

Logistics innovation	Focus & define
Cost reduction & innovation	O&M
Emerging market: China	Supply chain access

Source: Poulsen, 2018

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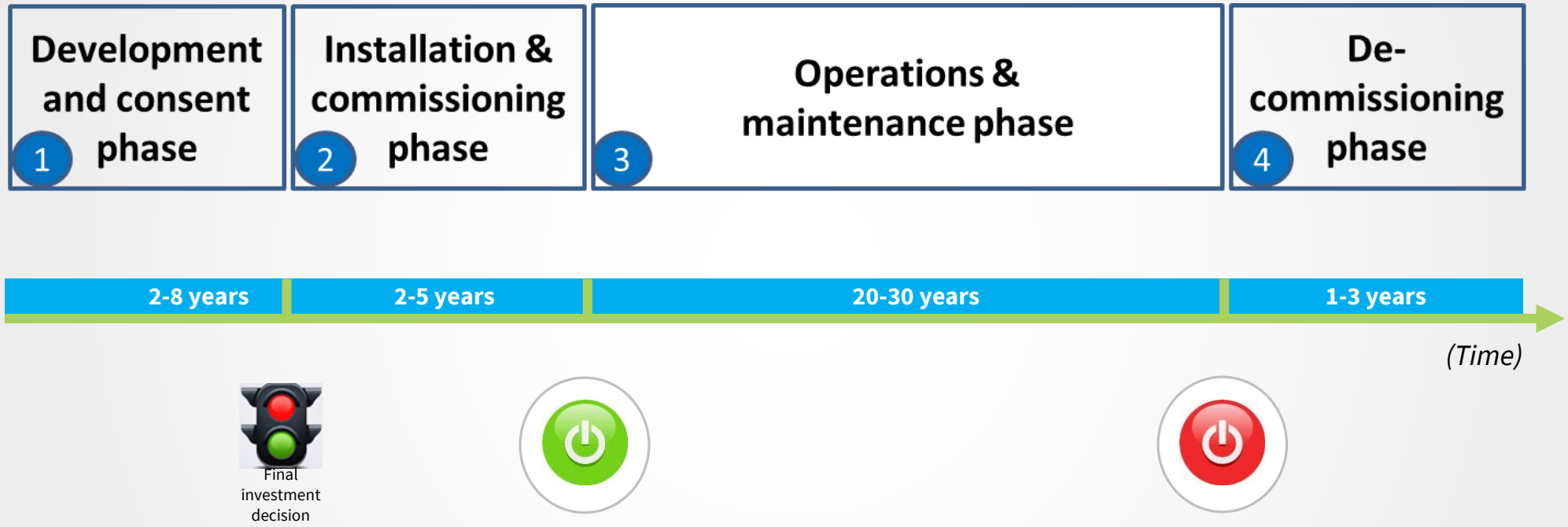
LIFE-CYCLE PHASES – FRAMING THE DISCUSSIONS



Source: Poulsen, 2015

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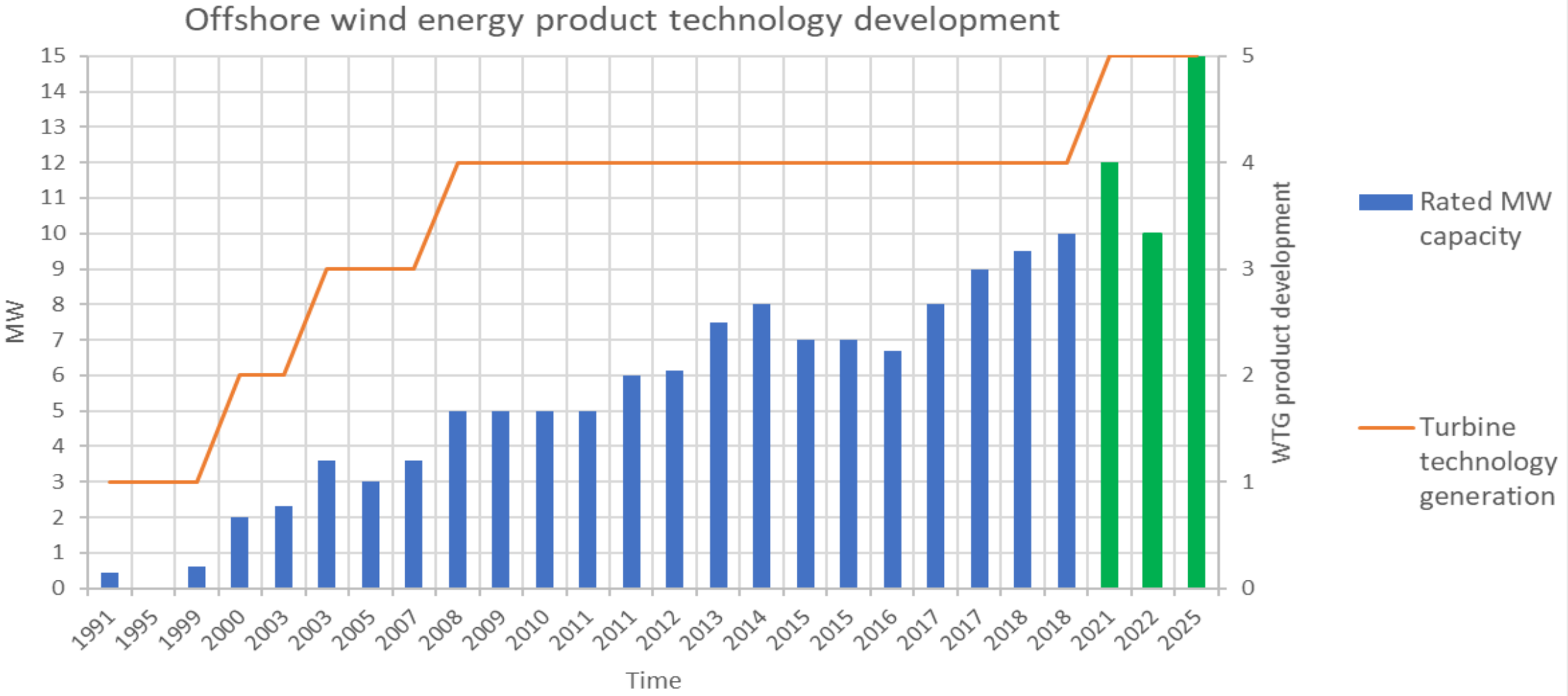
TURBINE PRODUCT DRIVES THE INDUSTRY



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NEXT GENERATION 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)



Source: Panticon analysis

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WEIGHTS, SIZE, AND DIMENSIONS

Weight & Dimensions	Full Nacelle Weight (t)	Nacelle dimensions (m)	Hub Weight (t)	Total Hub Mass (t)	Hub Height (m)	Blade Length (m)	Blade Weight (t)	Tower Weight (t)
Siemens 2.3 MW	82			142	80	45		162
Siemens 3.6 MW	140				80	58.5	18	
REpower 6.15 MW	325					61		
Siemens 6 (9) MW	364		96	360	135	75	27	
Samsung 7.5 MW						83		
MHI Vestas 8 (9.5) MW	390	20 x 8 x 8			105-140	80	35	
NREL/DTU 10 MW	446		106-180	700		86-100	42-57	628
GE 12 MW					150		107	
NREL/SGRE 15 MW			303	1000		125	100	1000
DTU 20 MW	1061		299			125	118	1985

Source: Panticon analysis

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TRENDS AFFECTING LOGISTICS (1)

- Offshore wind turbine size: Increased to average 5.3MW for 2017 installations in Europe
  - In Nov. 2017, Senvion announced it will launch a 10MW+ turbine in the early 2020s
  - In March 2018, GE announced plans to launch the 12MW Haliade X in 2021
  - Siemens Gamesa also working on the D1X platform 10+MW turbine (April 2018)
  - MHI-Vestas launched a 10MW in Sept. 2018
- Increased pressure on installation vessels as well as installation processes
- Offshore wind farm (OWF) size:
  - Less than 100MW by end of 2008 to nearly 500MW (average size OWFs under construction in 2017)
- Increase in average OWF distance from shore:
  - Up to 200km for OWF projects at early planning stage
- Driving trend in O&M strategy from land-based CTV set-up to sea-based set-up with helicopters, platforms, floatels, and/or SOVs
- Increase in average OWF depth: Roughly 50m for OWF projects at early planning stage
  - Monopile foundations' dominance expected to decline
  - Floating offshore wind foundations needed e.g. in Japan, US West coast (NREL estimates 58% of US optimal offshore sites suitable for floating technology)
  - Most planned OWF projects in Asia-Pacific are in deeper waters

Source: Panticon analysis

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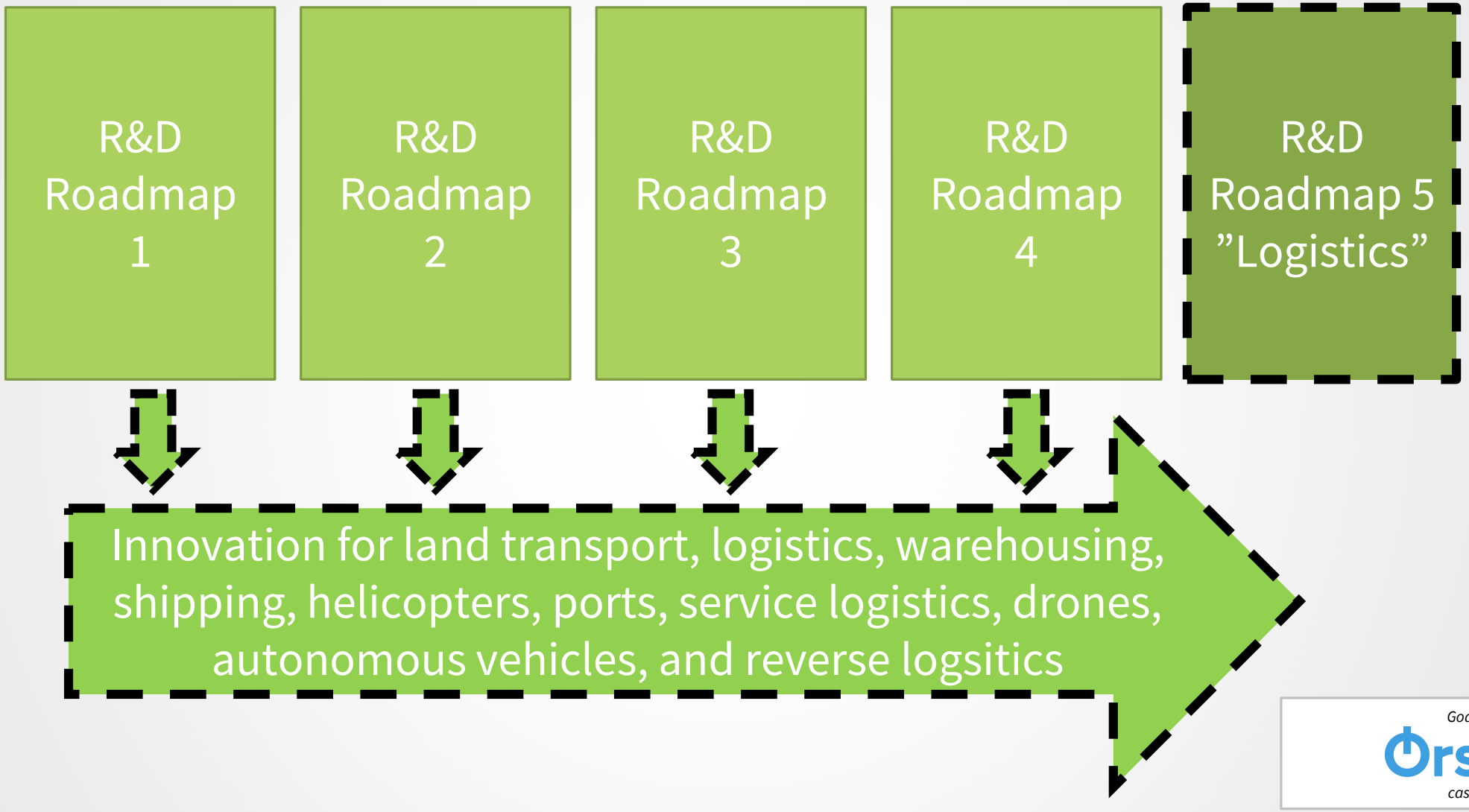
LOGISTICS INNOVATION



Goal of the Ørsted *case study*

Source: Poulsen & Hasager, 2016

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OFFSHORE WIND LOGISTICS - DEFINED

1. What	"Parts, modules, components, people, consumables, and tools
2. HSSEQ	are responsibly stored and moved safely,
3. Weather	weather permitting,
4. E2E	onshore, as well as offshore
5. Modes	by air/ocean/land
6. How	using various transportation assets and transport equipment
7. Focus	with a focus on an individual wind turbine generator, an offshore wind farm asset project, or across a portfolio of projects
8. Competencies	by means of different in-house and outsourced logistics skills/capabilities/IT systems
9. Multiple SCs	used across multiple supply chains
10. Start/end	spanning different starting and ending points,
11. Inventory carrying costs	also duly considering inventory carrying costs."

Source: Poulsen & Hasager, 2016

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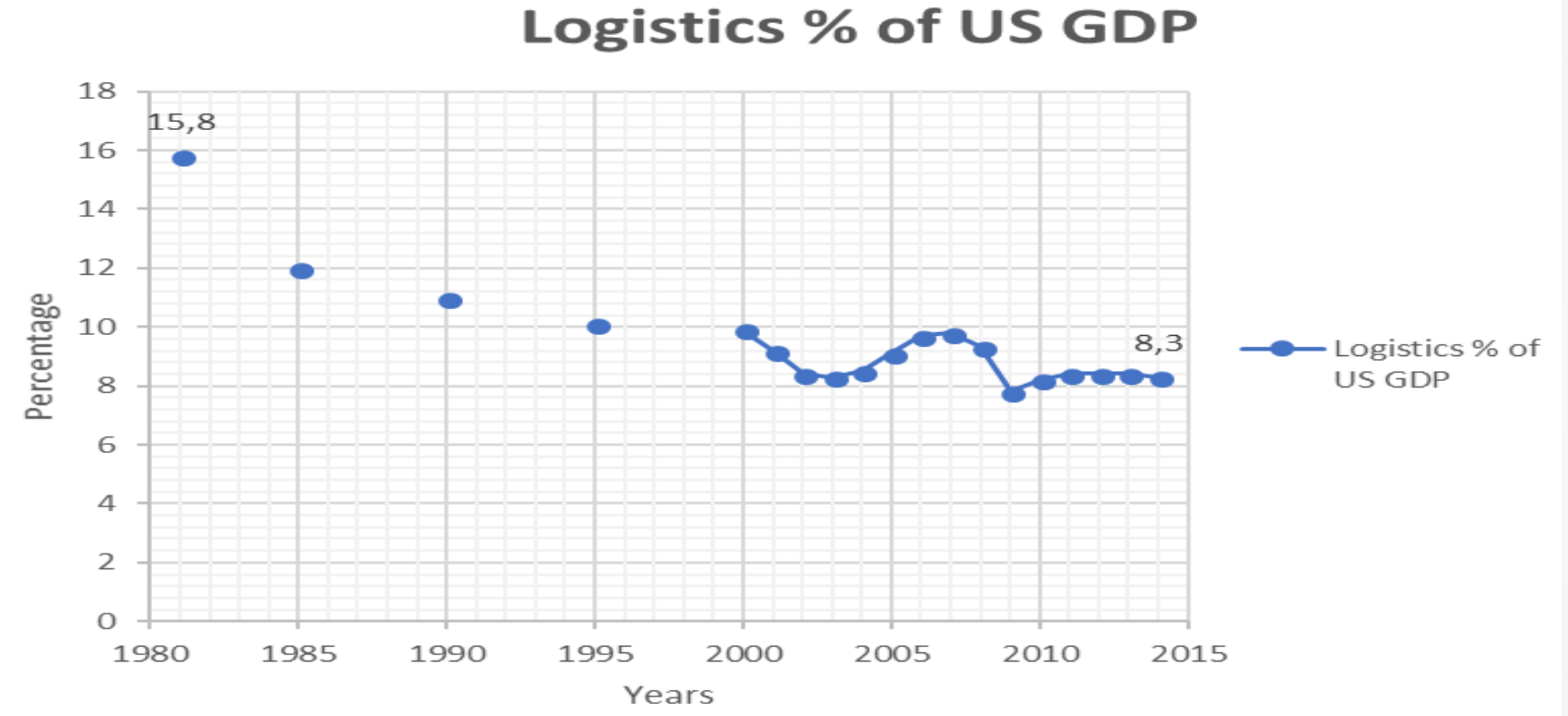
LOGISTICS COSTS OVER TIME – MEASURED IN THE US



47% reduction over 23 years

Source: CSCMP, 2015

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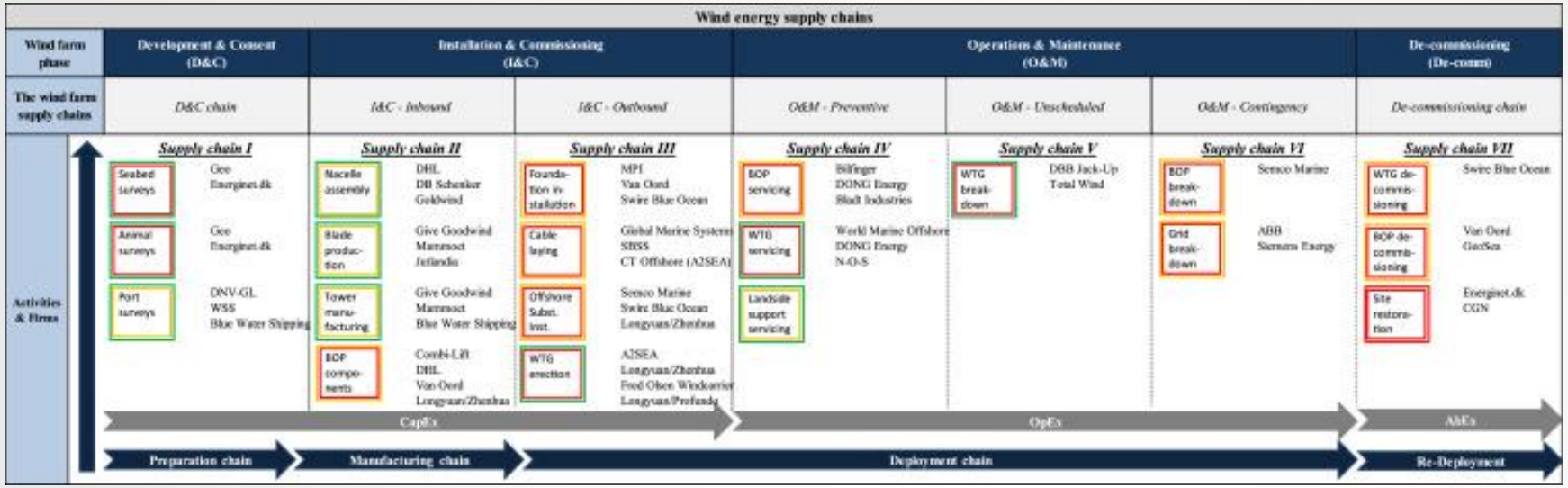
SUB-SUPPLY CHAINS AND COST FOCUS



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%

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)

> 90% of LCoE

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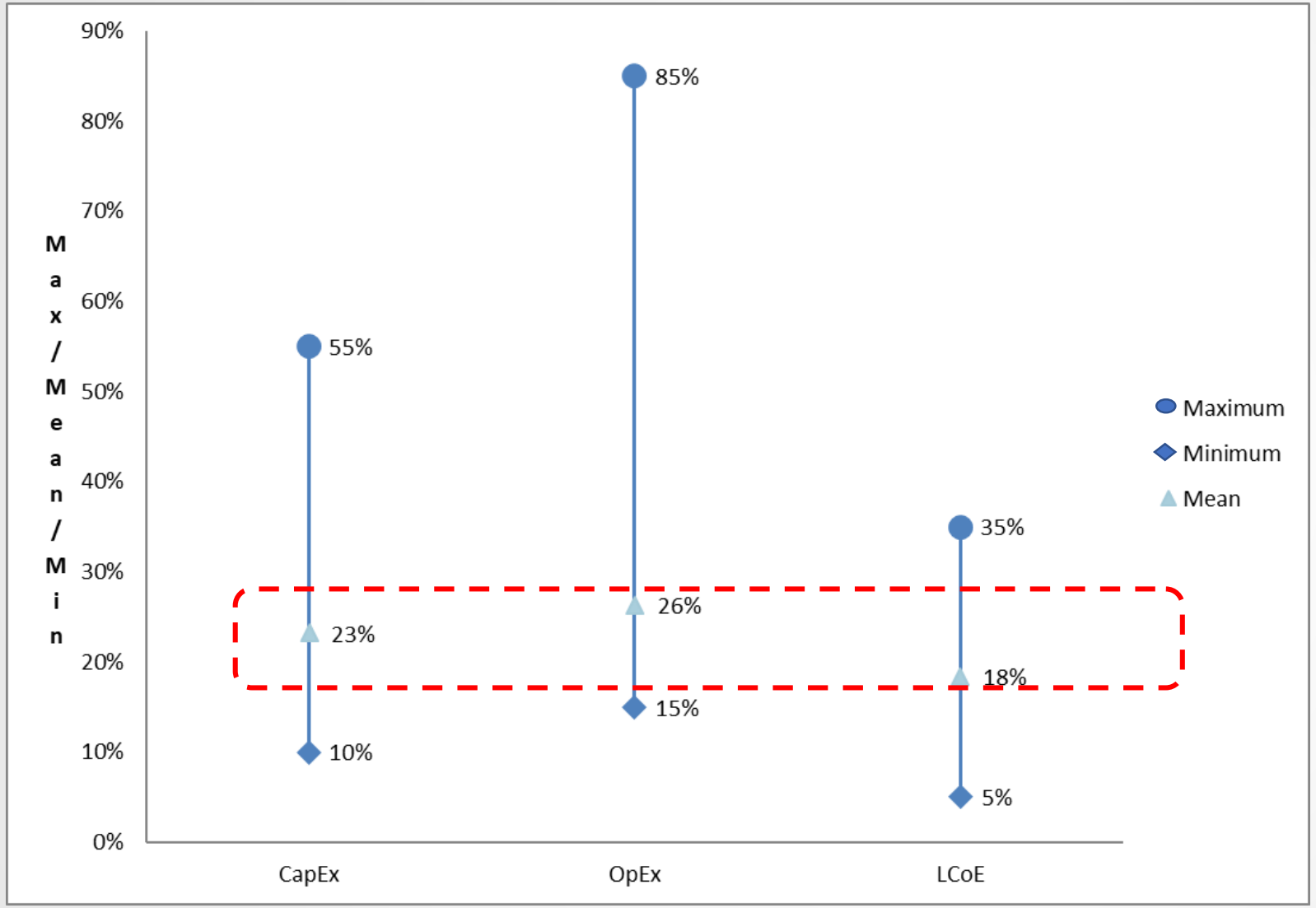
OFFSHORE WIND LOGISTICS - COSTS



Findings from the

Ørsted

case study

Legend:

CapEx	= Capital Expenditure
OpEx	= Operating Expenditure
LCoE	= Levelized cost of energy

Poulsen & Hasager, 2016

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NARROWING THE OPEX RANGE

Logistics costs as a share of operating expenditure	Minimum	Mean	Maximum
Ørsted case study	15%	26%	85%
O&M logistics case study	17%	24%	31%

Source: Poulsen & Hasager (2016), Poulsen et al. (2017)

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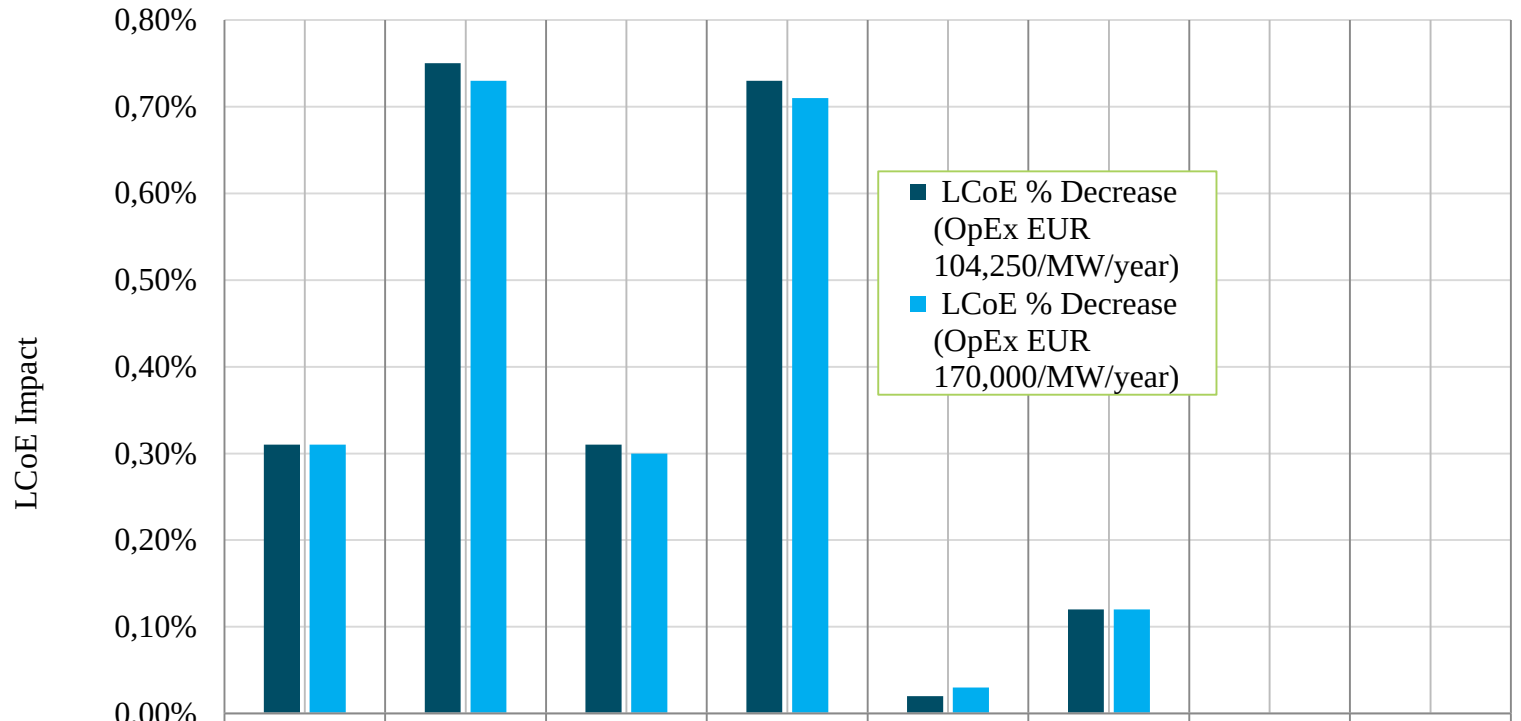
O&M LOGISTICS DEEP-DIVE



	Land-Based CTV Low Impact	Land-Based CTV High Impact	Sea-based CTV Low Impact	Sea-based CTV High Impact	Sea-based SOV Low Impact	Sea-based SOV High Impact		
LCoE % Decrease (OpEx EUR 104,250/MW/year)	0,31%	0,75%	0,31%	0,73%	0,02%	0,12%		
LCoE % Decrease (OpEx EUR 170,000/MW/year)	0,31%	0,73%	0,30%	0,71%	0,03%	0,12%		

Findings from the
OFFSHORE ENERGY.DK
O&M logisticscase study with support from
VATTENFALL

Source: Poulsen et al. (2017)

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ANALYSIS OF LOGISTICS COSTS

Year	Study
2015	Megavind LCoE calculator
2015	Douglas-Westwood offshore wind global forecast 2025
2014	BVG Associates UK Supply Chain Assessment
2013	Prognos and Fichtner Group Germany cost reduction
2013	GL Garrad Hassan offshore wind O&M spend guide for Scottish Enterprise and The Crown Estate
2012	The Crown Estate UK cost reduction pathways study including sub-studies in work streams
2011	Deloitte study on offshore wind competitiveness for Denmark
2010	BVG Associates/UK Renewables Advisory Board offshore wind sector value break-down report
2009	WindEurope report on the economics of wind energy
2009	Vattenfall VindKraft third annual technical report for Kentish Flats offshore wind farm
2007	Offshore Design Engineering offshore wind cost study for UK Department of Trade & Investment

Largely government sponsored; issued over 10-year period

Poulsen et al., 2017

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LOGISTICS LINE-ITEM ANALYSIS

Cost item	Minimum	Maximum
Port operations costs	1.2%	31%
Vessel costs (incl. helicopters)	9%	38%

Poulsen et al., 2017

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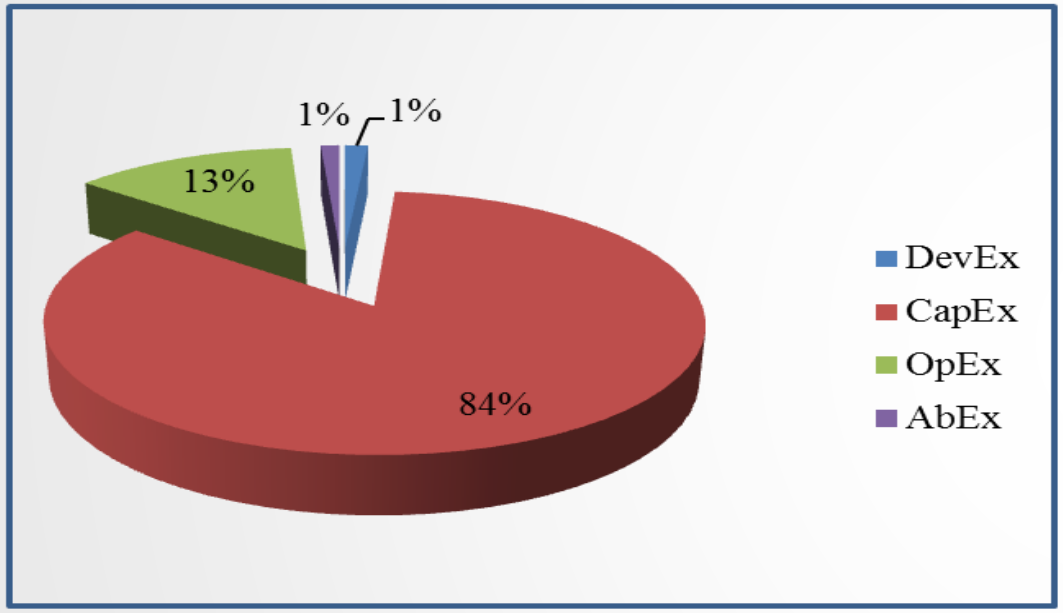
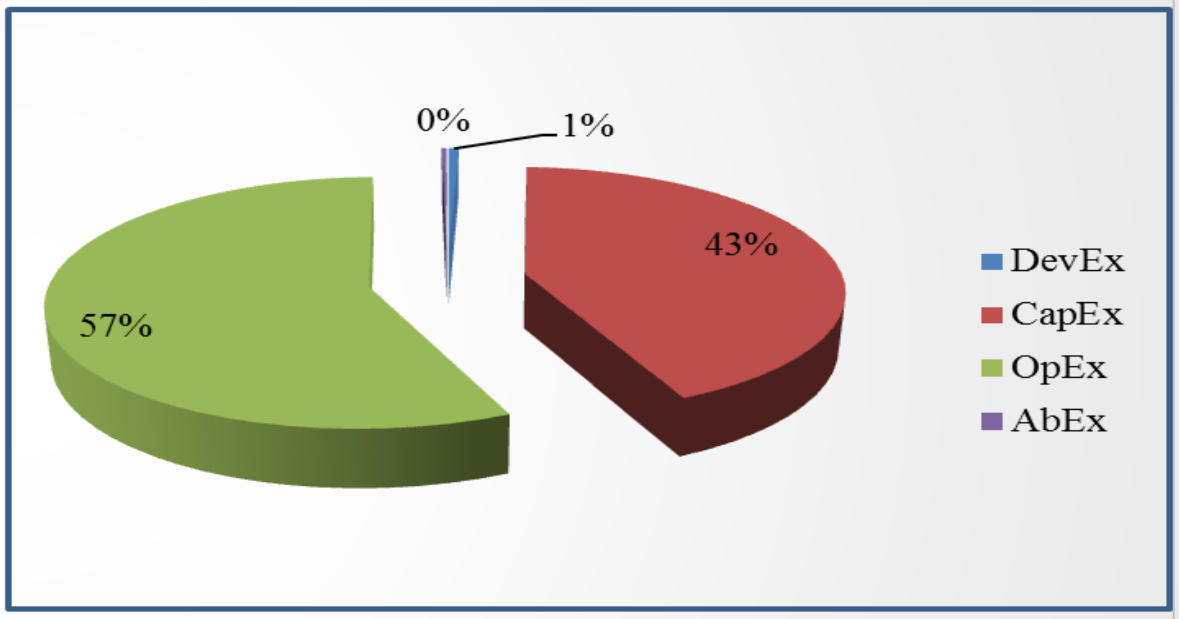
MODEL OPERATOR CAN DECIDE OUTCOME

Lowest OpEx cost per MW per year and lowest CapEx cost per MW implying a near-shore offshore wind farm with a land-based O&M strategy. Discounted OpEx makes up 13.1% of the total costs



Highest OpEx cost per MW per year and highest CapEx cost per MW implying a far offshore wind farm with a sea-based O&M strategy. Discounted OpEx now makes up 56.5% of the total costs



Key modelling assumptions include WACC of 10% (The Crown Estate 2012), OpEx and AbEx numbers have been discounted according to the project operating life assumptions, lowest OpEx example includes a "normal" O&M life-cycle phase of 20 years' opearting life whereas highest OpEx example includes a "prolonged" O&M life-cycle phase of 25 years' operating life, and AEP/DevEx/AbEx numbers for the model simulated based on Megavind (2015). Eight (all from 2010 or later) of eleven studies (Megavind 2015; Douglas-Westwood 2015; BVG Associates 2014; Prognos and Fichtner Group 2013; GL Garrad Hassan 2013; The Crown Estate 2012; Deloitte 2011; BVG Associates 2010) in our analysis are included in thse numbers

Source: Poulsen et al., 2017

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LOGISTICS GAPS IN EMERGING CHINA

1. Logistics related studies (road, seabed, environmental)
2. Vessels custom built for offshore wind (piling hammer, cable laying, wind turbine installation, crew transfer)
3. Developers contract offshore wind turbine installation (not turbine manufacturers as in Europe)
4. BOP supply chain not built out incl. logistics
5. Offshore wind O&M concepts sought based on real experience/operational data
6. De-commissioning and reverse logistics in offshore wind
7. Cost models and planning tools across all life-cycle phases

Source: Poulsen & Hasager, 2017

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TRENDS AFFECTING LOGISTICS (2)

Also in Asia, the landscape for utilities is changing

- In China, the Central SOEs (SASAC managed), with backgrounds in coal, nuclear and hydro power generation, are embracing offshore wind and dominate ownership of operational, under construction as well as planned OWFs projects in China
  - In Q4 2017, Guodian Group, owner of China's then number 1 offshore wind developer – China Longyuan Power, was merged into coal powerhouse Shenhua Group. Shenhua Group has since been renamed China Energy Investment Corporation Limited (China Energy Group)
- In South Korea, state utility KEPCO and its group of companies, whose power generation portfolio is preeminently fossil fuel or nuclear-based, dominate offshore wind project pipeline ownership
- In Taiwan, 87.6% of the 5.5GW awarded so far is owned by foreign players
- In Japan, trading houses look to dominate, with some exceptions
  - The other APAC markets, e.g. India, Vietnam, Singapore, look set to follow "Taiwan model"
  - Singaporean and Thai players have already expressed interest in the Taiwanese and Vietnamese offshore wind markets

Source: Panticon analysis

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SUPPLY CHAIN READINESS - LOGISTICS

	0	1	2	3
Supply chain #II - Inbound to manufacturing				
Nacelle				EU, PRC
Tower				EU, PRC
Blades/hub				EU, PRC
Wind turbine foundation monopile/transition piece		PRC	EU	
Wind turbine foundation jacket	PRC	EU		
Onshore sub-station/booster station			PRC	EU
Offshore sub-station/booster station		PRC	EU	
Offshore sub-station foundation		PRC		EU
Export cables	PRC			EU
Array/infield cables		PRC		EU
Supply chain #III – Installation and commissioning				
Onshore sub-station/booster station			PRC	EU
Offshore sub-station/booster station	PRC	EU		
Export cables	PRC	EU		
Array/infield cables		PRC	EU	
Wind turbine/offshore sub-station foundations		PRC	EU	
Wind turbine generator		PRC	EU	

Legend:

0 = blocks

1 = negative impact

2 = limited impact

3 = positive impact

Installation example

Poulsen & Lema, 2017

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FOCUS ON GLOBAL EMERING MARKETS

- **Emerging Europe – offshore wind**
  - Holland
  - Belgium
  - France
  - Portugal
  - Finland
  - Poland
  - Turkey
- **Emerging Americas – offshore wind**
  - USA
  - Canada
  - Brazil
- **Emerging Asia – offshore wind**
  - **China** ← *PhD research publication focus area*
  - Taiwan
  - Japan
  - South Korea
  - India
  - Vietnam
  - Australia
  - Singapore
  - Thailand
  - Bangladesh

Source: Panticon analysis

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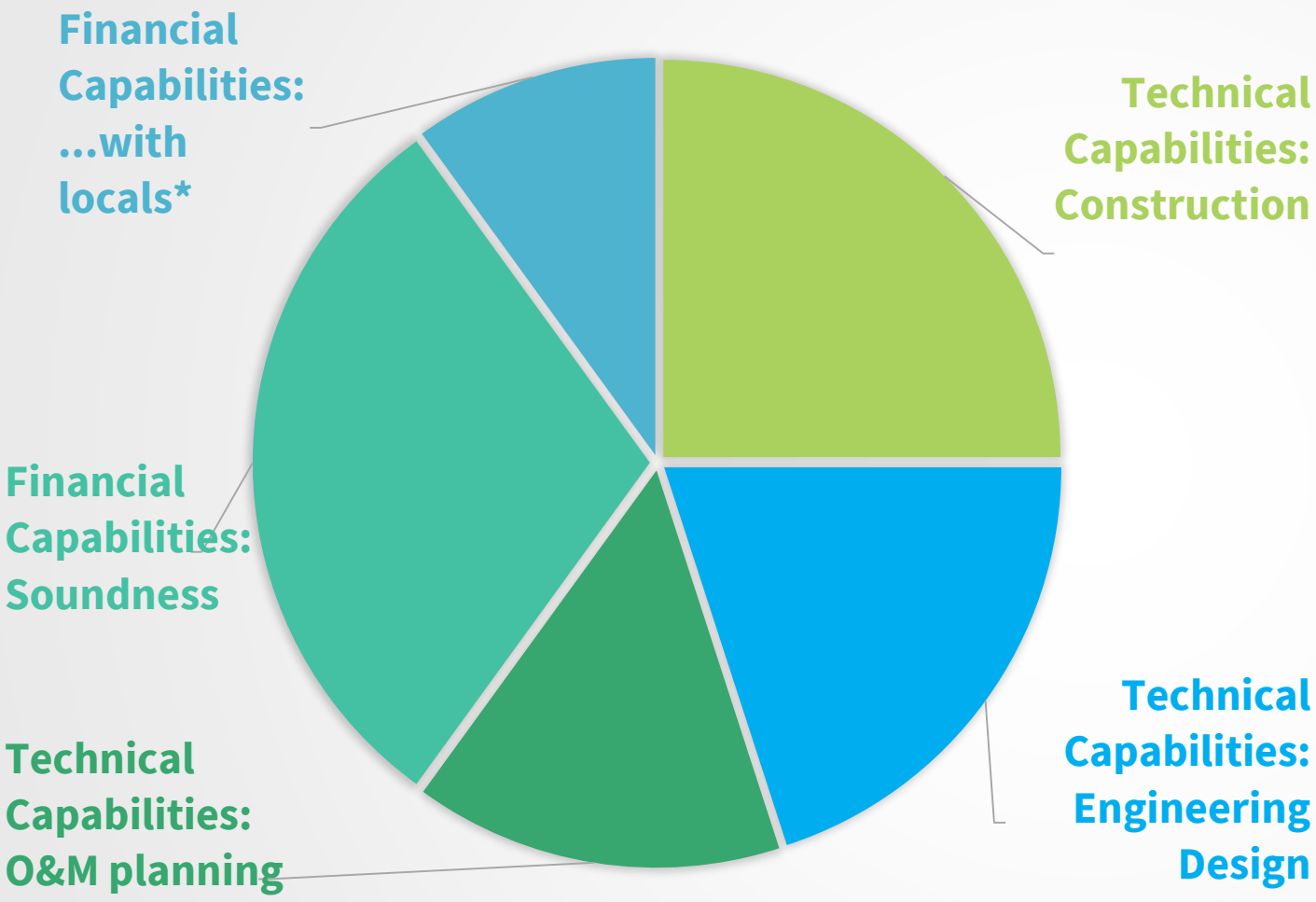
TAIWAN – A NEW FRONTIER WITH 5.5 GW AWARDED



- 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

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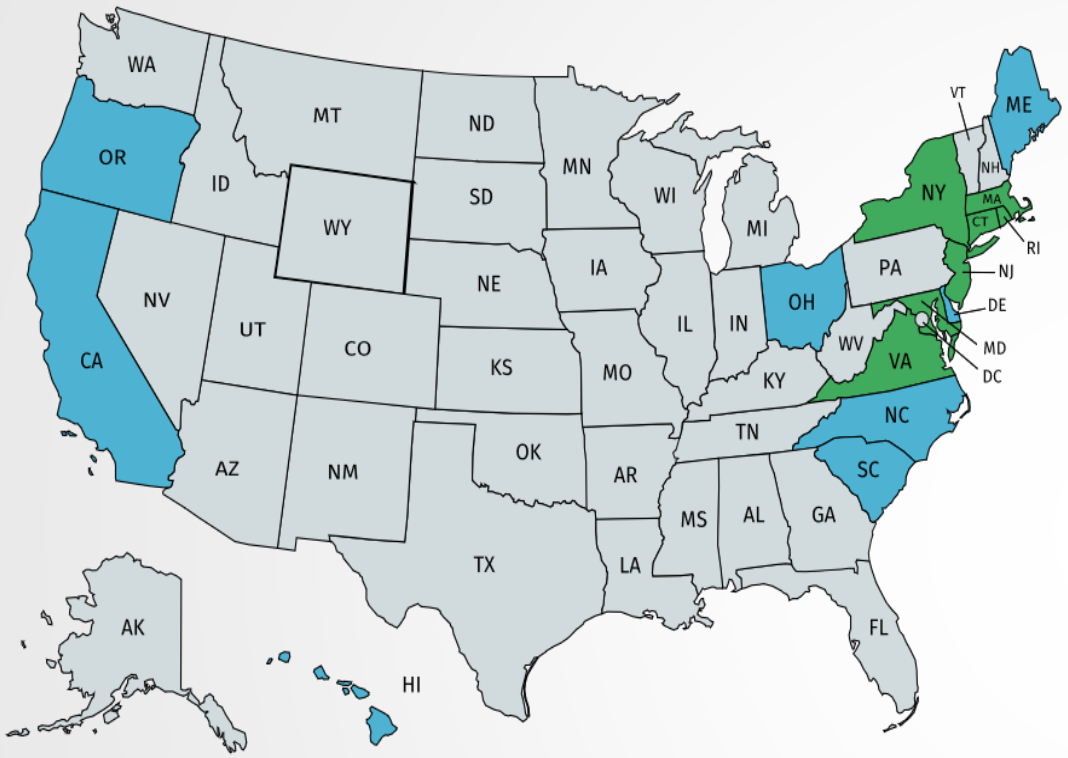
USA – NEARLY 2 GW AWARDED ACROSS 4 STATES



- 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) is investing in steelworks and port facilities in the Greater Baltimore area (120 MW Skipjack project)

Shipping and logistics:

- Merchant Marine Act of 1920 (the Jones Act)

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TRENDS AFFECTING LOGISTICS (3)

- Europe still has the most advanced offshore wind project pipeline
- Markets emerging outside Europe
  - Mainly in Asia-Pacific and the Americas
  - Encouraged by European success, declining costs in Europe, and European players' search for new markets (high competition)
  - Improved regulatory set-ups and market structures as knowledge is transferred from Europe
- From subsidies (e.g., FIT schemes) to auctions to zero subsidies (post-2020 reality in Europe; China likely to follow suit)
- Intensifying LCoE reduction measures
- Increasing industry collaboration to reduce LCoE at various stages of the offshore wind farm (OWF) lifecycle
  - O&M clusters
- Increasing role of institutional investors (e.g. CIP, PFA, PKA) starting at construction phase of the OWF lifecycle
- Higher debt-to-equity ratio in project financing thanks to growing investor confidence

Source: Panticon analysis

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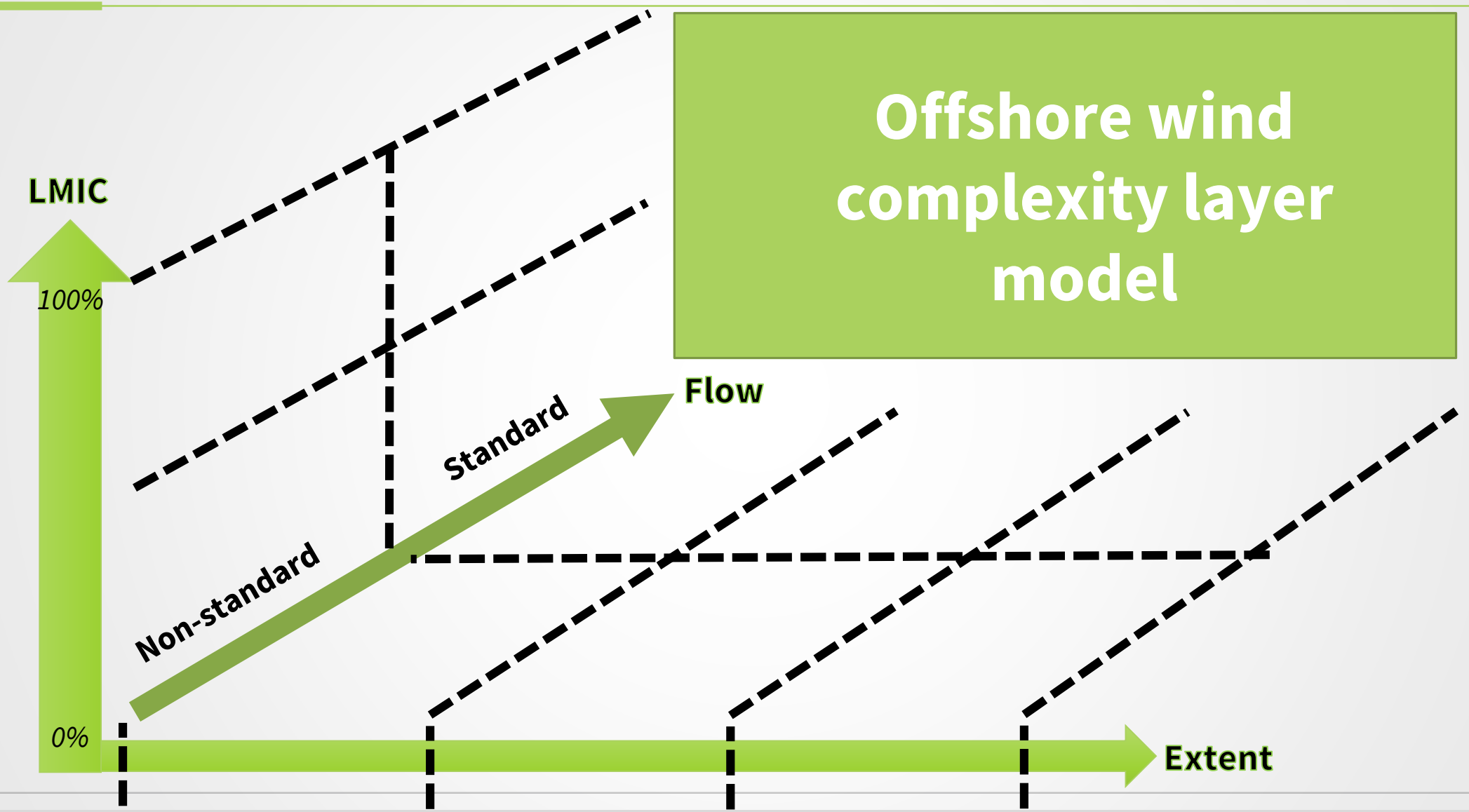
NOISE IN THE LOGISTICS CHAINS – ROOT CAUSES



Source: Panticon analysis

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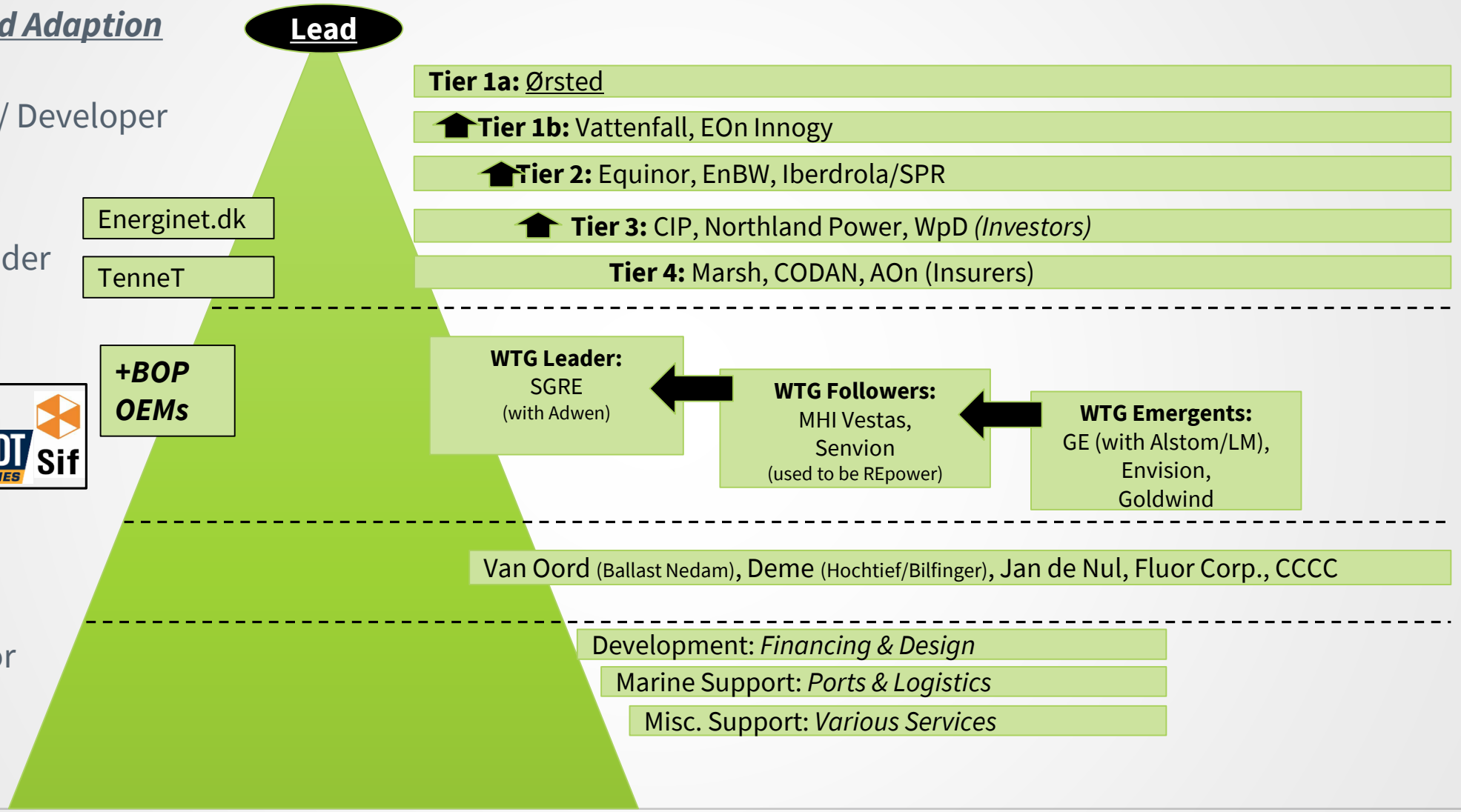
SUPPLY CHAIN LEAD FIRMS – CONTRACT STRUCTURE

Offshore Wind Adaption

- ❑ Operator / Developer
- ❑ Grid provider
- ❑ OEM
- ❑ EPCi
- ❑ Contractor



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GREEN IS THE NEW BLACK

- Major regional and global oil & gas players transitioning/committing to renewables (offshore wind)

DONG Energy (Denmark) spun off O&G activities
- World leader in offshore wind
- Involved in Taiwan, USA, and far offshore wind farms (Hornsea)
- Rebranded to Ørsted (Nov '17)

Vattenfall (Sweden)
- Significant offshore wind presence
- North Europe focus only
- Company moving away from nuclear and coal

E.On (Germany) span off conventional energy businesses (Nov'14/Jan'16)*
- Involved in roughly 1GW operational offshore wind portfolio in four European countries (Denmark, Germany, Sweden & the UK), 385MW under construction, and 2.1GW planned

British Petroleum (UK) rebranded to Beyond Petroleum (Jul'00)* though not successful

Statoil (Norway)
- Launched Hywind Scotland floating offshore wind farm in 2017
- Key developer for Dogger Bank far offshore wind farms
- Emerging offshore wind markets (Poland, USA)
- Rebranded to Equinor (May '18)

Royal Dutch Shell (UK/Holland) committed to move core business from hydrocarbons to electricity (June 2016)
- Led a successful consortium bid for the 731.5MW Borssele III/IV OWF in the Netherlands in Dec. 2016*
- Invested in UK start-up company Kite Power Systems that develops high-altitude wind power generation technology (Dec. 2016)*
- Took part in India's April 2018 EOI for 1GW OWF*
- Applied to bid for BOEM offshore wind lease in Massachusetts (Jul '18)*
- Qualified to bid for BOEM North Carolina offshore wind lease in 2017 but did not bid

Eni (Italy)
- Entered agreement with GE to develop renewable energy projects and hybrid solutions with focus on energy efficiency (Nov'16)*
- Entered agreement with Statoil (Equinor) to jointly assess opportunities in the integration of renewable energy solutions in existing oil and gas fields (Mar' 17)*
- Took part in India's April 2018 EOI for 1GW OWF via subsidiary Saipem*

GDF Suez (France) changed name to ENGIE (Apr'15)*
- Involved in roughly 1GW OWF consented projects in France*
- Signed MoU with Japan's J-Power to collaborate on large-scale OWF projects (Sept. '18)*
- Took part in India's April 2018 EOI for 1GW OWF

Total (France) core business to move from hydrocarbons to electricity
- Invested in distributed onshore wind power with United Wind (US) (Jul'16)* but yet to invest in offshore wind
- Acquired battery designer Saft (Jul'16)*
- Acquired renewable energy company Eren* (Sept. '17)

- Key drivers:
  - Global transition towards decarbonization and combating climate change
  - Pressure from shareholders
  - Reaping the benefits of a "new" industry

Source: Panticon analysis

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CLOSING REMARKS

Management consulting

Non-executive member of select Supervisory Boards of Directors

Questions and answers

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SAMPLE CONSULTING CLIENTS

Strategic Management Advisory

Mergers & Acquisitions

Market Research & Analysis







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SELECT PARALLEL PROJECTS

Projects for companies and organiations

- Delegation trip to China for 50+ people for Norwegian Energy Partners and Offshoreenergy.dk
- Report for Innovation Norway and Norwegian Energy Partners on how value chain synergies may be derived between Norway and Denmark
- Offshore wind market entry strategy for major freight forwarding and logistics company
- Work with supplier clusters like Offshore Center Bornholm, Kriegers Flak Service Group, and Offshoreenergy.dk to set strategy, implement strategy, and be external project manager
- Next generation installation vessel market entry implementation project for Canadian shipping company
- Set up Danish offshore wind division of a Norwegian oil & gas industry player
- Transport strategy including IT and health/safety for major wind turbine manufacturer
- Partnership with BVG Associates where we cover the Nordics/Baltic area plus Asia with clients like Norwegian Energy Partners
- Project manager in installation logistics project to implement common lifting guidelines and transport equipment design standards across wind turbine manufacturers in offshore wind
- Demand forecast up to 2030 including oil & gas and offshore wind converted into area expansion strategy for major port

Member of supervisory Boards of Directors

- Head Energy (Bergen)
- BHS Logistics (Rønne)
- Turnkey Group (HK)

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scan GLOBAL LOGISTICS

Envision

RØNNE HAVN A/S COMMERCIAL PORT OF BORNHOLM

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THANK YOU FOR YOUR ATTENTION

QUESTIONS & ANSWERS



THOMAS POULSEN
Managing Partner

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Address: Vivede Møllehuse 15, 4640 Faxe, Denmark
E-mail: tp@panticon.com | Mob: +45 - 212 661 88
Websites: www.windscm.com | www.panticon.com



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