



GLOBAL WIND ENERGY SHIPPING AND LOGISTICS

PHD RESEARCH PROJECT
7TH REFERENCE GROUP MEETING

AUGUST 24, 2016, DANISH SHIPOWNERS' ASSOCIATION, COPENHAGEN

Proprietary, private, and confidential



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Today's program

12:30-13:15 Working lunch

13:15-14:30 Meeting part I

14:30-15:55 Coffee and meeting (II)

15:55-16:00 Ready for “gå-hjem”

16:00-18:00 “Gå-hjem” meeting

Working lunch



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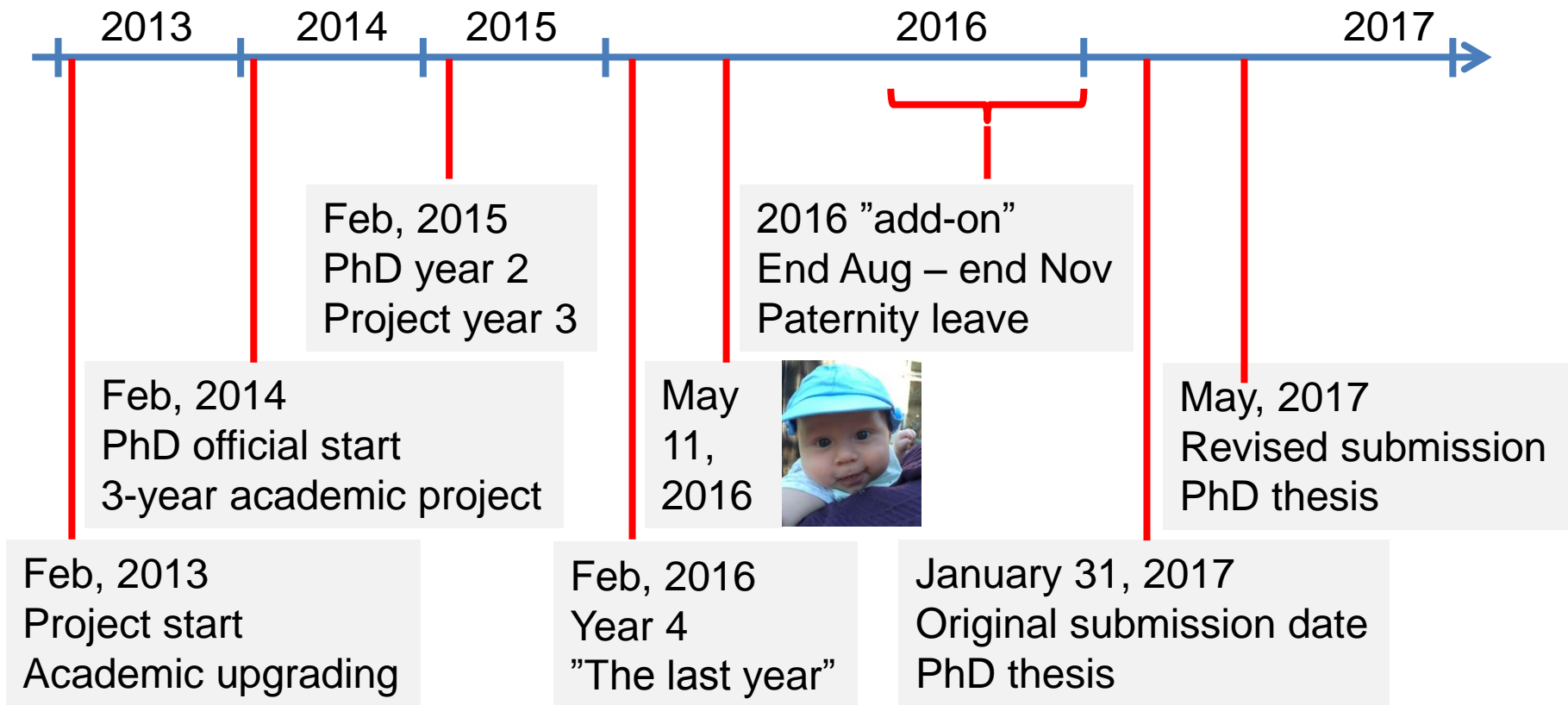


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Agenda – Reference Group

1. **Meeting opening, welcome, and agenda review** during working lunch
2. **New/changed Reference Group member organizations / changed participants** – short introduction by new participants
3. Detailed review of **the logistics share of operating expenditure** as well as **operations and maintenance**
4. **Short review of scoping of PhD research project** efforts from first meetings
5. **Key activities since last meeting.** Focus on:
 1. The “**speed boats**” from the **PhD “mother vessel”**
 2. **Government relations and tailor-made grants** (Horizon 2020)
 3. **Concurrent dissemination** of research results and findings
6. **Update on academic progress**, 11-month plan, and plans going forward
7. **Wrap-up, preparation for “gå-hjem” meeting, and date/venue for next meeting**

Changed PhD planning



Brief introductions

(organizations, participants)



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Intro to new/changed Reference Group participants



- Quick personal background
- Brief overview of the activities of your organization
- Expectations from participation in the Reference Group and research project

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Recap of March 2016 meeting

O&M part 1



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Last meeting: Practical O&M

- Maade – 2x 8MW WTGs incl. O&M
- SubCpartner – O&M with focus on substructures and ROVs
- Esvagt – SOVs for far shore offshore wind farms



The logistics share of OpEx and O&M

O&M part 2



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A percentage of...what?!

When working with LCoE, people often answer questions with a **percentage value**.

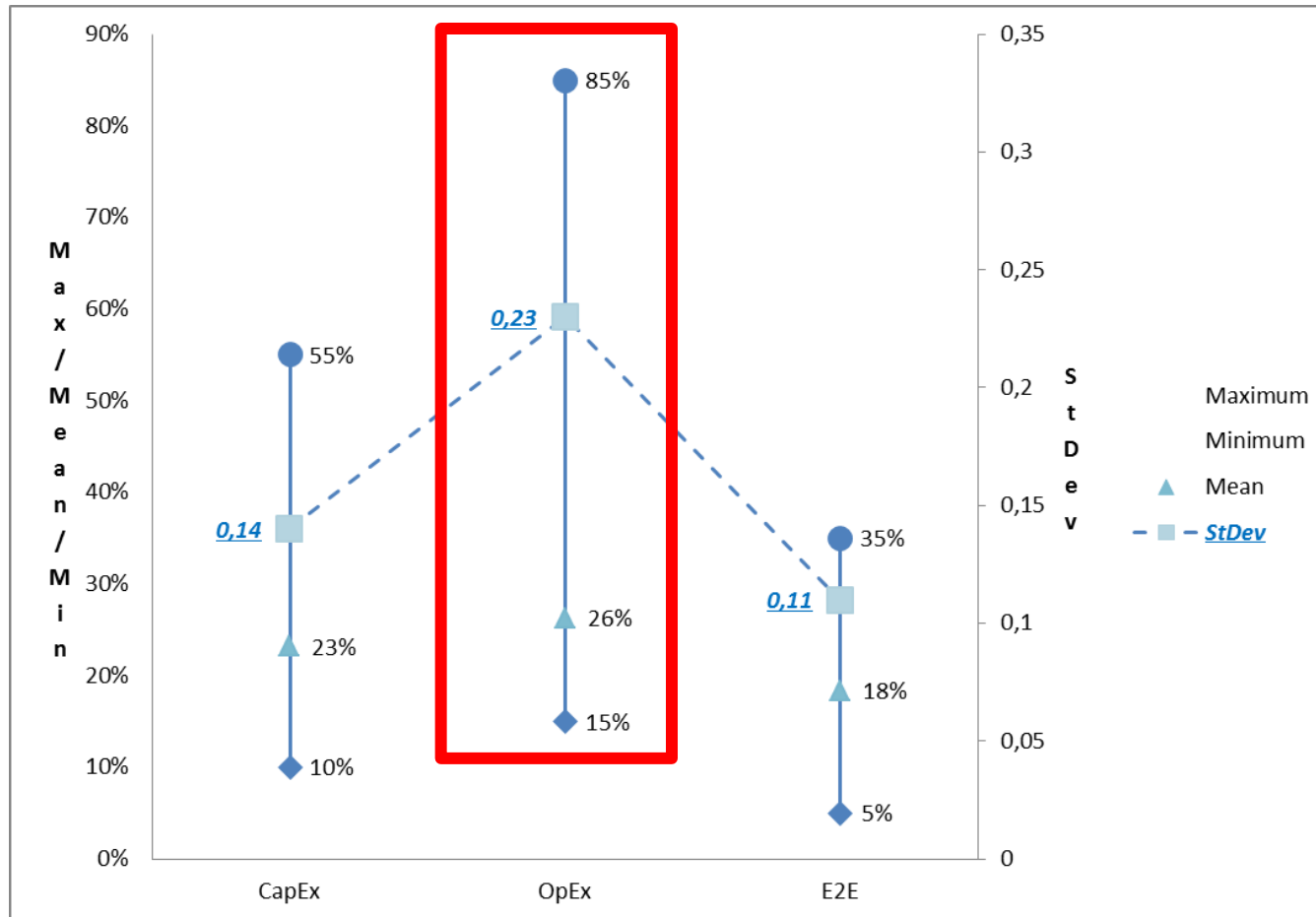
We always ask: "**Percentage of what?**"

The **answers** are generally **VERY different**.

Within **O&M**, this seemed to be **more true** than for any other life-cycle phase.

So, we decided to **investigate this further...**

Example: Our DEWP case study...



O&M had largest spread in answers provided

- *Logistics as a percentage of...*
- *OpEx!!!*
- *...O&M?*

Analysis of 11 different studies

| Year | Study | Cost itemization |
|------|---|---|
| 2015 | Megavind 2015 LCoE calculator | Built-in template data based on 400 MW OWF modeled after Danish Anholt OWF. Contains up to 15 OpEx/O&M cost line items with 7 pre-suggested types of which none can be attributed to logistics |
| 2015 | Douglas-Westwood offshore wind global forecast 2025 | Forecast up to 2025 of global OWFs. Defines OpEx as a percentage range of CapEx costs. Breaks OpEx down into 6 cost items of which 3 can be directly attributed to logistics |
| 2014 | BVG Associates UK Supply Chain Assessment | 500 MW OWF using 6 MW WTGs. Operation, maintenance, and service costs defined as 39% of lifetime costs. O&M costs split between minor service and major service with cost items defined but not further broken down |
| 2013 | Prognos and Fichtner Group Germany cost reduction | Extensive study with 3 different sites ranging from 320 to 450 MW OWFs modeled with 4, 6, and 8 MW WTGs based on distance to shore and water depth. O&M costs modeled for different scenarios and costs provided per MW per year. Insurance costs are separated |
| 2013 | GL Garrad Hassan offshore wind O&M spend guide for Scottish Enterprise and The Crown Estate | 500 MW OWF using 6 MW WTGs. OpEx cost items broken down into 18 line items of which 5 can be fully attributed to logistics. OpEx provided per line item |
| 2012 | The Crown Estate UK cost reduction pathways study including sub-studies in work streams | Extensive study with 4 different 500 MW sites modeled based on distance to shore, water depth, and wind speeds. Operating costs estimated at 33% of total LCoE (page 15) |
| 2011 | Deloitte study on offshore wind competitiveness for Denmark | Study considers O&M to be out of scope (page 4) |
| 2010 | BVG Associates UK Renewables Advisory Board offshore wind sector value break-down report | 500 MW OWF using 5 MW WTGs. 5 O&M cost items discussed including operation, maintenance, and license fees. One cost item is port activities. Costs also segmented into labour, materials, and other where "other" includes vessels and cranes. |
| 2009 | European Wind Energy Association report on the economics of wind energy | The report is largely built based on onshore wind technology and findings except one section on offshore wind based on 2 MW WTGs and a park capacity of 160-200 MW. The onshore wind O&M break-down has 5 line items of which none can be attributed to logistics. Offshore wind O&M defined as a cost per MW/h |
| 2009 | Vattenfall VindKraft third annual technical report for Kentish Flats OWF | 30 WTG OWF with 3 MW capacity. 6 OpEx cost items including administration, insurance, lease & rent. O&M under warranty from OEM. Estimated OpEx costs broken down per line item. |
| 2007 | Offshore Design Engineering OW cost study for UK Department of Trade and Investment | Early study based on 30 WTGs each with 3.6 MW capacity, near shore. 5 OpEx cost items of which 4 were WTG related and 1 related to vessels. OpEx costs set as a percentage of CapEx. |

LCoE components

- DevEx = Development expenditure
- CapEx = Capital expenditure
- OpEx = Operating expenditure
- AbEx = Abandonment expenditure

Definition of OpEx

“...includes **all expenditure** occurring **from immediately after point of takeover**, whether **one-time or recurring**, related to the wind farm, measured on an **annual basis**.

Excluded are expenses inherent to the operation of the operators business but **not directly related to the operation and management of the wind farm**”

Dimensions of the 11 studies

| Study Name | Year | Study Examines | O&M to OpEx | Currency | Simulated or Actual Cost Reduction | WTG Cap? [MW] | Farm Cap? [MW] | Life-cycle phases |
|---------------------------------------|------|----------------|-------------|----------|------------------------------------|---------------|----------------|-------------------|
| Megawind | 2015 | OpEx | 1 | EUR | | Open | Open | All |
| Douglas-Westwood | 2015 | OpEx | 1 | EUR | Simulated | N/A | N/A | All |
| BVG UK SC | 2014 | OpEx | 1 | GBP | Simulated | 6 | 500 | No de-comms |
| P + FG Germany cost reduction | 2013 | OpEx | 1 | EUR | Simulated | | | |
| Scottish Enterprises GL Garrad Hassan | 2013 | O&M | 2 | GBP | | 6 | 500 | |
| TCE UK cost reduction | 2012 | OpEx | 1 | GBP | Simulated | 4, 6 | 500 | |
| Deloitte DK study | 2011 | N/A | N/A | N/A | | | | Only CapEx |
| UK RAB 2010 | 2010 | OpEx | 1 | GBP | | | | |
| EWEA2009 | 2009 | O&M++ | 1.5 | EUR | Simulated | 2 | 160-20 | |
| KF Vattenfall | 2008 | O&M++ | 1.5 | GBP | Actual | 3 | 90 | |
| ODE UK study | 2007 | O&M | 1.5 | GBP | Simulated | 3,6 | 108 | |

Unit of analysis - OpEx

- % of CapEx
- % of total lifetime costs
- % of LCoE per MW/h
- Per WTG per year
- Per MW per year
- Per MW/h
- For total OWF per year
- Line-item absolute costs

Megavind (2015)

- Publically available LCoE calculator
- The LCoE calculator used Anholt OWF as default
- Breakdowns for wind farm in to 6 major cost items
 - Support Structure
 - Wind Turbine
 - Export Cable
 - Offshore Substation
 - Onshore Substation
 - Array cable
- Two scenarios tested
 - Spread of 155%!

Douglas-Westwood (2015)

- OpEx related to CapEx (per MW per Annum)

| Type | Amount of Annual OpEx |
|---|-----------------------|
| Replacement equipment | 51% |
| Personnel transfer | 9% |
| Skilled technicians | 8% |
| Installation / repair vessels | 6% |
| O&M ports | 5% |
| Grid maintenance, lease & other recurring costs | 21% |

- Two scenarios tested
 - OpEx is 3% of CapEx per annum
 - OpEx is 12% of CapEx per annum
- Spread of 400%!

GL Garrad Hassan - ScotExec (2013)

- Good breakdown of O&M costs
 - 18 points from onshore admin, to cable surveys, to weather forecasting included.
 - Not perfect... no insurance or vessel availability.
- Maximum and minimum projected O&M costs
- Spread of 232%!
- Spread reduces to 212% with insurance.

OpEx \neq O&M

- O&M can explain approx. 50% of OpEx
 - Early studies on onshore wind reflected approx. 50%
 - Early studies of offshore wind reflected approx. 60-75%
 - Most recent study shows approx. 54% for offshore wind

Non-O&M parts of OpEx

Non-O&M variable costs/OpEx

- Transmission assets / grid use of system charges / payments to offshore transmission owner
- Seabed rent
- Insurance
- Weather windows
- Lost revenue
- Vessel availability

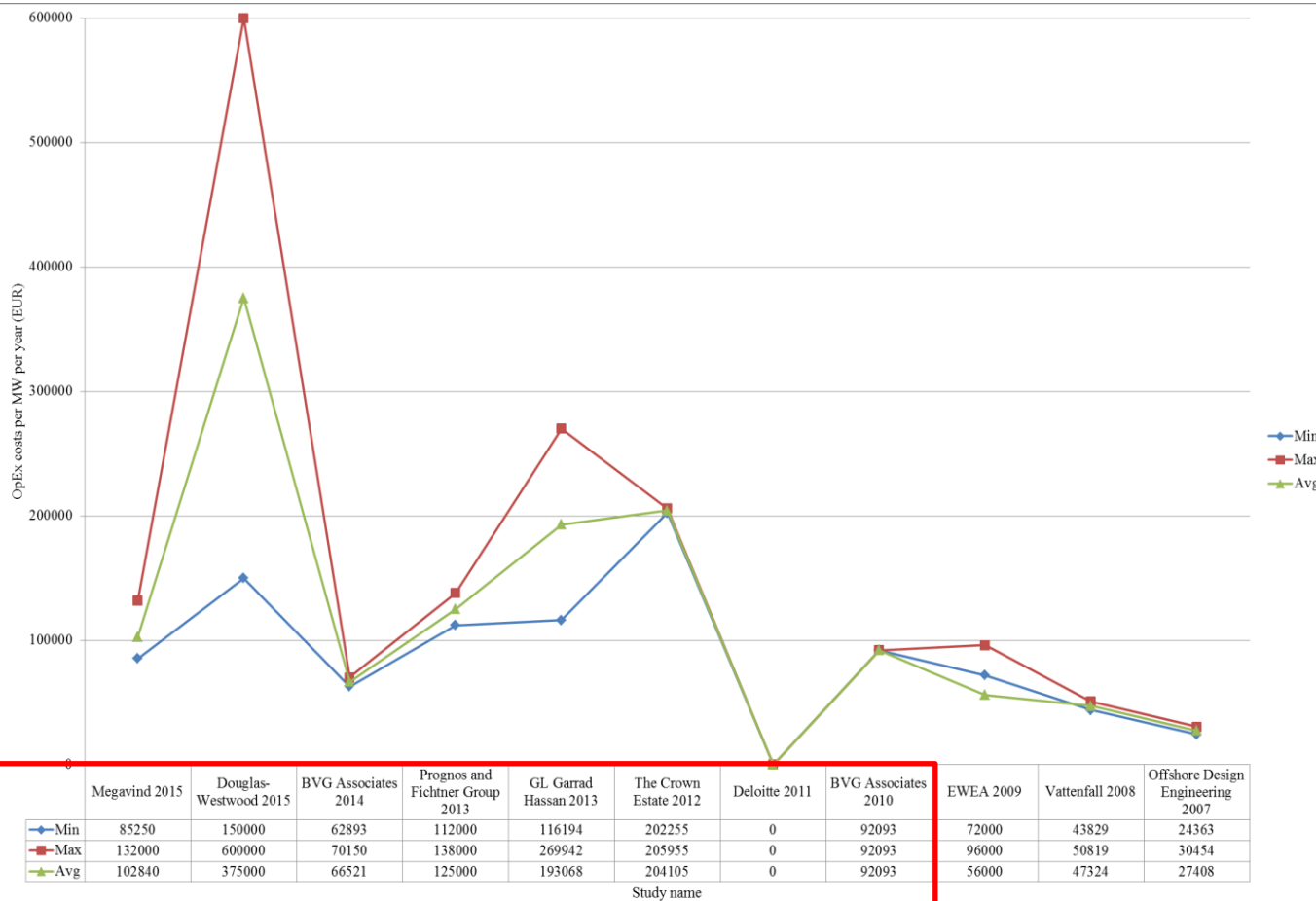
O&M in other industries (academia)

- Oil & Gas:
 - IMR = inspection, maintenance, and repair
 - IRM = inspection, repair, and maintenance (subsea)
- M&R = shipping, construction, and electricity industries
 - Maintenance & *repair*
 - Maintenance & *renewal*
 - Maintenance & *replacement*
 - Maintenance & *rehabilitation*

Differences in LCoE calculations

1. **WTG rating** = bigger output; less positions; higher insurance premia
2. **WACC** = 1% increase in WACC is 6% LCoE increase -> O&M key risk factor
3. **Distance to shore** = near and far shore offshore wind farms
4. **Water depth** = foundation types
5. **Initial WTG warranty period** = paid for by CapEx costs; not part of OpEx
6. **Variable or linear OpEx costs** = change over time or fixed; repowering; end-of-life
7. **Learning curve** = savings over time

Low/high OpEx spread: 9.5x

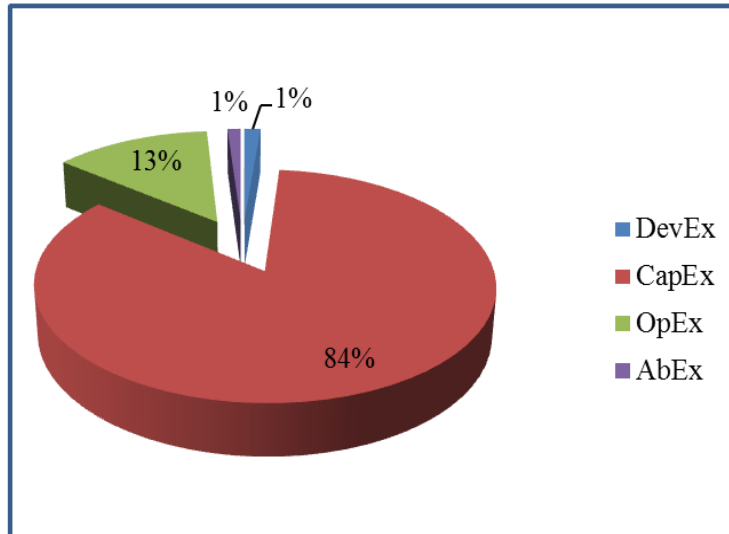


Later studies separate near and far shore

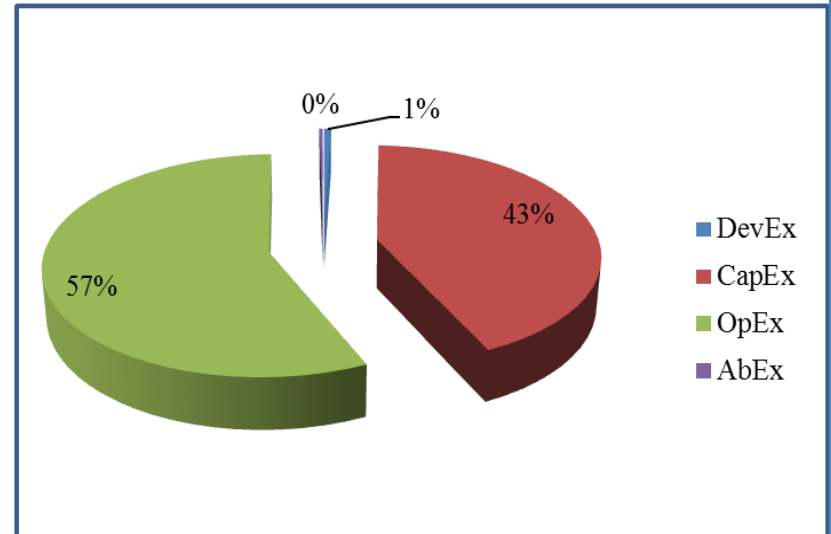
- Minimum OpEx EUR 62,893 /MW/year.
- Average OpEx EUR 166,895 /MW/year
- Maximum OpEx EUR 600,000/ MW/year

Low/High: OpEx share of LCoE

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' operating 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 these numbers

Defining the logistics share

| O&M cost line item | LF |
|--|-----|
| 1. Shore base | 1 |
| 2. CTVs | 1 |
| 3. Helicopters | 1 |
| 4. WTIVs | 1 |
| 5. Fixed platform or floating (floatel, SOV) | 0.7 |
| 6. Skilled personnel | 0 |
| 7. Excl. storage and sourcing | 0 |
| 8. Inspections, services, repairs, paint, WTIVs, CTVs | 0.4 |
| 9. Surveys, repairs, ROV, CLVs | 0.8 |
| 10. Skilled personnel, some logistics | 0.1 |
| 11. Surveys, repairs, ROV, CLVs | 0.8 |
| 12. Divers, ROVs, surveys, inspections, repairs, survey vessels | 0.8 |
| 13. Paint, cleaning, grout, scour, repairs, lighting, vessels | 0.8 |
| 14. Inspections, drills, certified personnel, vessels | 0.6 |
| 15. Data monitoring, analysis | 0 |
| 16. On-site senior authorized person, monitoring of vessels/personnel 24/7 | 1 |
| 17. Wind, wave, atmospheric pressure, precipitation, temperature, visibility | 0 |
| 18. Financial reporting, PR, procurement, inventory management/HSSEQ management/permits management, administration | 0.2 |

Major differences exist

- Port operations costs

Min 1.2%

Max 31%

- Vessel costs (incl. helicopters)

Min 9%

Max 38%

Logistics share of OpEx

| | Minimum cost levels | Maximum cost levels |
|--|---------------------|---------------------|
| Line items with a logistics factor of 100% | 17% | 32% |
| Line items with any logistics factor | 17% | 30% |
| Overall average | 24% | |

Groups on OpEx and O&M - the logistics share

Group #1 Near shore vs far offshore

Group #2 Topside vs subsea

Group #3 Planned and unplanned

3 groups

Please nominate:

- Captain
- Time-keeper
- White board note taker
- Presenter

Please be ready to:

- Recap the question
- Provide your answer
- Explain your discussions
- Review your findings on the flip-chart
- Answer questions from the group

The groups

- #1 Christian, Thomas (AHI), Silja, Per
- #2 Charlotte, Lars, Henrik, Hans, Chris
- #3 Thomas (DSA), Helle, Johan, Kim, Anders

Please be back at...

14:45 PM

Presentation of group results



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Presentations

***Flip-chart presentations
from the 3 groups***

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Scoping from first meetings



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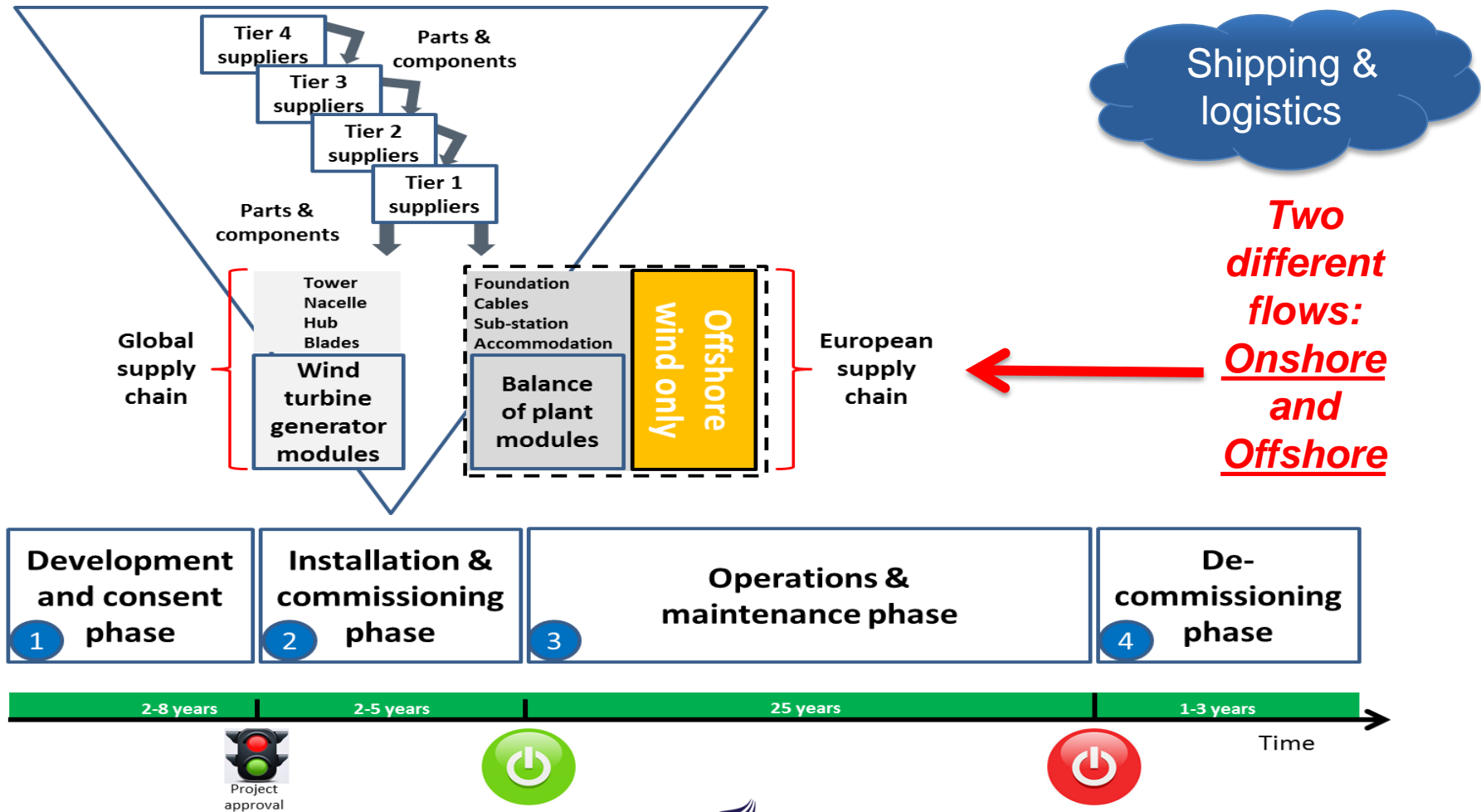
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Charter

The Reference Group will:

- Remain in *active existence* throughout the life-span of the research project
- Convene *twice per year*
- Meetings *at member organization* venues
- *Actively partake* in the research project
- Facilitate the *research project* internally in member organizations, and externally
- Support the on-going *research efforts*

End-to-end life-cycle focus



Shipping, logistics, SCM, end-to-end: *What does it really mean?*

Conclusion:

“The inbound to manufacturing assembly supply chain consists of “standard transportation” mainly by ocean and some air. This part of the end-to-end supply chain was therefore considered less interesting for the project to review than installation & commissioning, operations & maintenance, and decommissioning”

| Theory / Practice linkage | Support / Lobby | Challenges /Solutions |
|--|---|----------------------------------|
| Learn biz | Convey info | Practical and relevant / correct |
| Chinese market network sharing | Investments going forward (vessels, financing, etc.) | Practical background → tools |
| Reducing LCoE | Project timelines | Academia vs. consulting |
| Applied research | Offshore wind knowledge | Capture change |
| Good quality research | Case studies | Look at change in future |
| Scope: Narrow, realistic, big, complex, crystalize, etc. | Continuous “smart” goals: Concrete, specific, look ahead, value | Moving research target (in time) |
| On-time project | E2E wind supply chain | Bridge more industries |

Case study efforts

Number of companies

Time spent

Extent of case study scope

Depth

Width

Europe

Offshore, simple and easy cases

Asia

Offshore, one case

Americas

Onshore, rail focus

Wind energy shipping and logistics: Involved parties...

Freight forwarders:

- Global
- Regional
- Local

Ocean transportation and related:

- RO/RO (“Roll-on/Roll-off”)
- LoLo (“Lift-on/Lift-off”)
- Short-sea/regional operators
- Tug/barges and landing crafts (“LCTs”)
- Multi-purpose vessels (“MPV”)/Floating cranes
- Container vessel operators
- Safety vessels, work boats, and crew/hotel vessels
- Special vessels like offshore wind turbine installation and cable laying vessels

Ports

Storage:

- Warehouses
- Yards
- Storage areas

Rail

Specialty trucks

Land based cranes

Utilities

Operators

OEM's

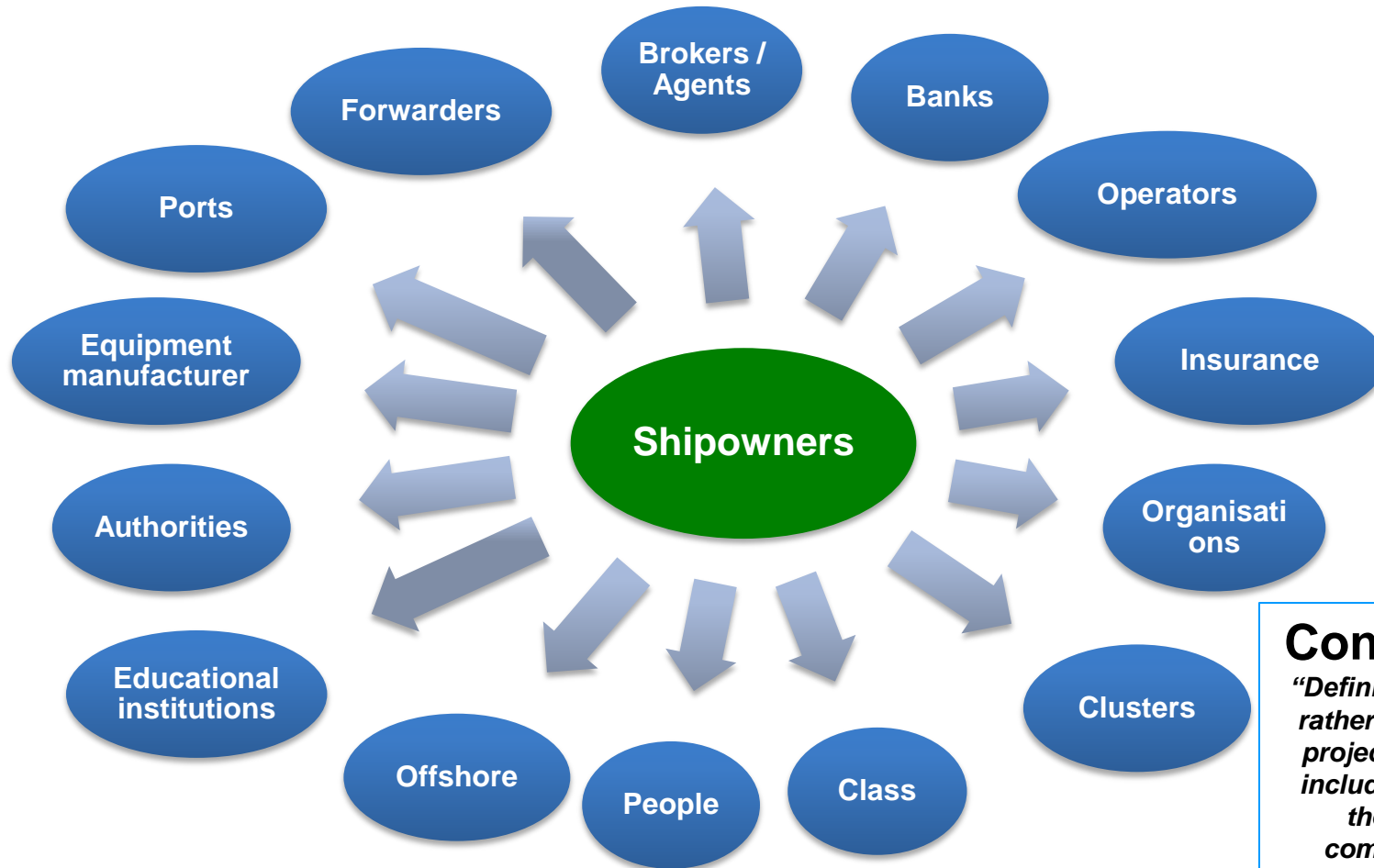
EPC companies

SWF



← Extent of services →

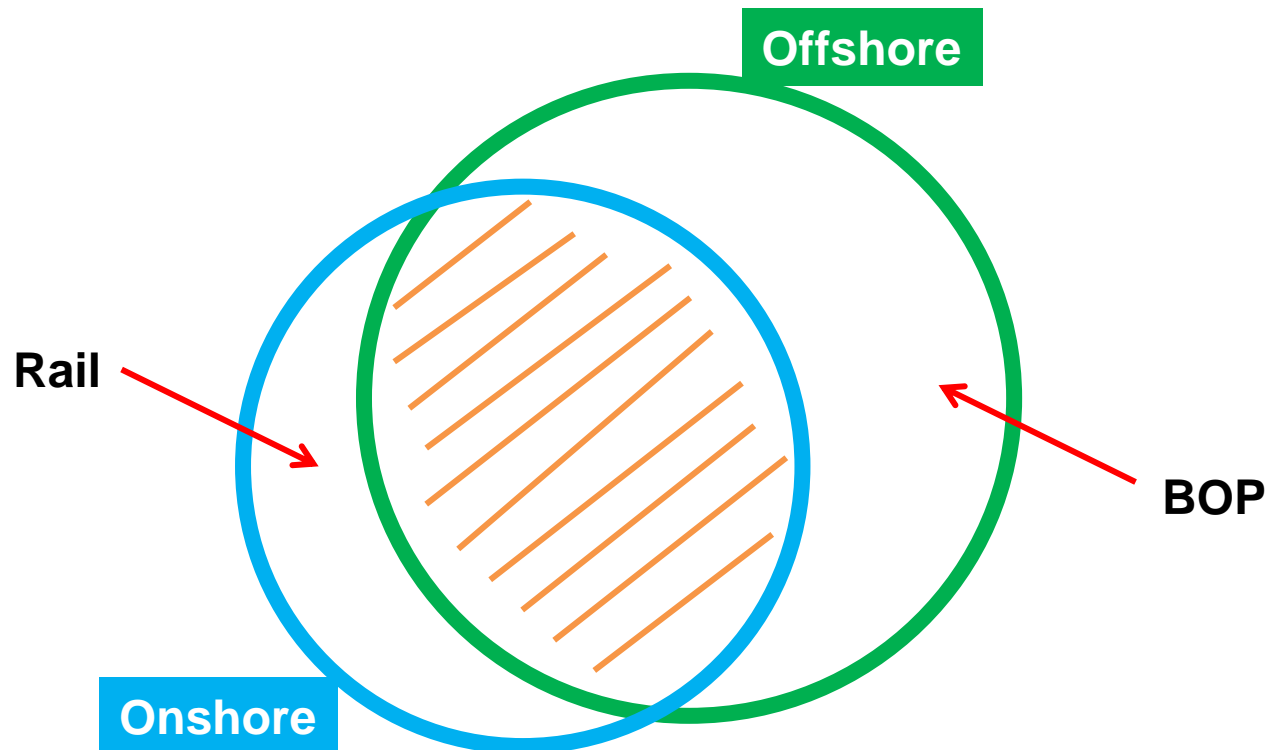
Definition of “The blue Denmark”



Conclusion:

“Definition should be rather broad for this project and not just include for example the shipping companies/DSA members”

Onshore and offshore SCM



Onshore and offshore wind – Differences and similarities

Conclusion:

“Whereas both similarities and differences exist between the onshore and offshore wind farm supply chains, the offshore wind supply chain is more complex in terms of shipping and logistics”

| Similarities | Differences |
|---|--|
| Inland: <ul style="list-style-type: none">- Same trucks / Equipment- Daytime- Infrastructure | Sea carriage: <ul style="list-style-type: none">- Assembly to site (outbound) |
| Port storage: <ul style="list-style-type: none">- Temp. storage | Infrastructure: <ul style="list-style-type: none">- Quayside loading / logistics- Diff. equipment (vertical)- Area / space (buffer)- Seamen education (outbound)- BOP- Installation / equipment / skills |
| Actual maintenance | Maintenance <ul style="list-style-type: none">- Certificates- Transportation- Equipment |

Scoping of the Ph.d. research

First Reference Group meeting scoping conclusion:

| Wind energy supply chains | | | | | | |
|---------------------------|---|---|--|---|---|--|
| Wind farm phase | <i>Development & Consent (D&C)</i> | <i>Installation & Commissioning (I&C)</i> | | <i>Operations & Maintenance (O&M)</i> | | <i>De-commissioning (De-comm)</i> |
| Supply chains | D&C chain | I&C chain - Inbound | I&C chain - Outbound | O&M - Preventive | O&M - Breakdown | De-comm chain |
| Description | Site surveys, birds, wildlife, sea, seabed | Inbound assembly parts and components | Outbound wind modules for wind farm site | Personnel, parts, and components | Personnel, parts, components, and modules | Restoration of site for new wind farm or to original condition |
| Characteristics | Specialized vehicles (onshore) and vessels (offshore) | Mainly a homogenous flow using ocean containers and air; some project cargo | Project cargo/break-bulk | Mainly service boats, crew transfer vessels and some larger vessels | Service boats and helicopters, some large vessels like MPV, tug&barge, WTIV | Project cargo/break-bulk |

Assumed to have the largest possible impact on potential reductions of levelized cost of energy



Achievements since last meeting



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Speed boats - CRF

Offshoreenergy.dk “Cost Reduction Forum”

- Group 4 logistics O&M
 - Case study involvement reduced
 - Journal paper writing WIP
- Group 3 INNOlog kicked off
 - Scoping completed and framework developed
 - Review of prior work now WIP

Speed boats – RM5 Logistics

DONG Energy Wind Power logistics
R&D RM5 Logistics strategy project

- Strategy proposal submitted to DONG Energy July 22, 2015
- Journal paper published in June, 2016 (and tracking extremely well)
- New RM5 Logistics Manager will be hired and in place by end of 2016
- New logistics Product Line established in August, 2016

Speed boats – China OW

5 visits since 2013 (total time spent in China ~2 months)

- Gap analysis China offshore wind as of end 2015 completed
- Possible 6th and last visit being considered
- Paper writing process in planning stages

Government relations - and tailormade grants



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EU Commission lobbying

March 2015 Reference Group success:

- Meeting with EU Commission officials
March 3, 2015 in Brussels



- Meeting with EU Commission officials at
EWEA Offshore March 11, 2015 in
Copenhagen



EU future research agenda

- Former EU research umbrella TPwind now replaced by ETIP Wind:
 - European Technology and Innovation Platform on Wind Energy
 - Only AAU representative for expert interviews in April – June time frame
 - Strategic Research and Innovation Agenda 2016 report will be published on September 27, 2016

Dissemination of research results and findings



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Concurrent dissemination

Academic

- Journal papers:
 - Theoretical contribution paper **published** in April, 2016 (IJESM)
 - DONG Energy Wind Power case study paper **published** in June, 2016 (Energies)
 - Manuscript for paper on supply chain readiness **submitted**

Industry

- Gå-hjem meeting on March 9, 2016 in Esbjerg
 - 50 people attended

Academic update

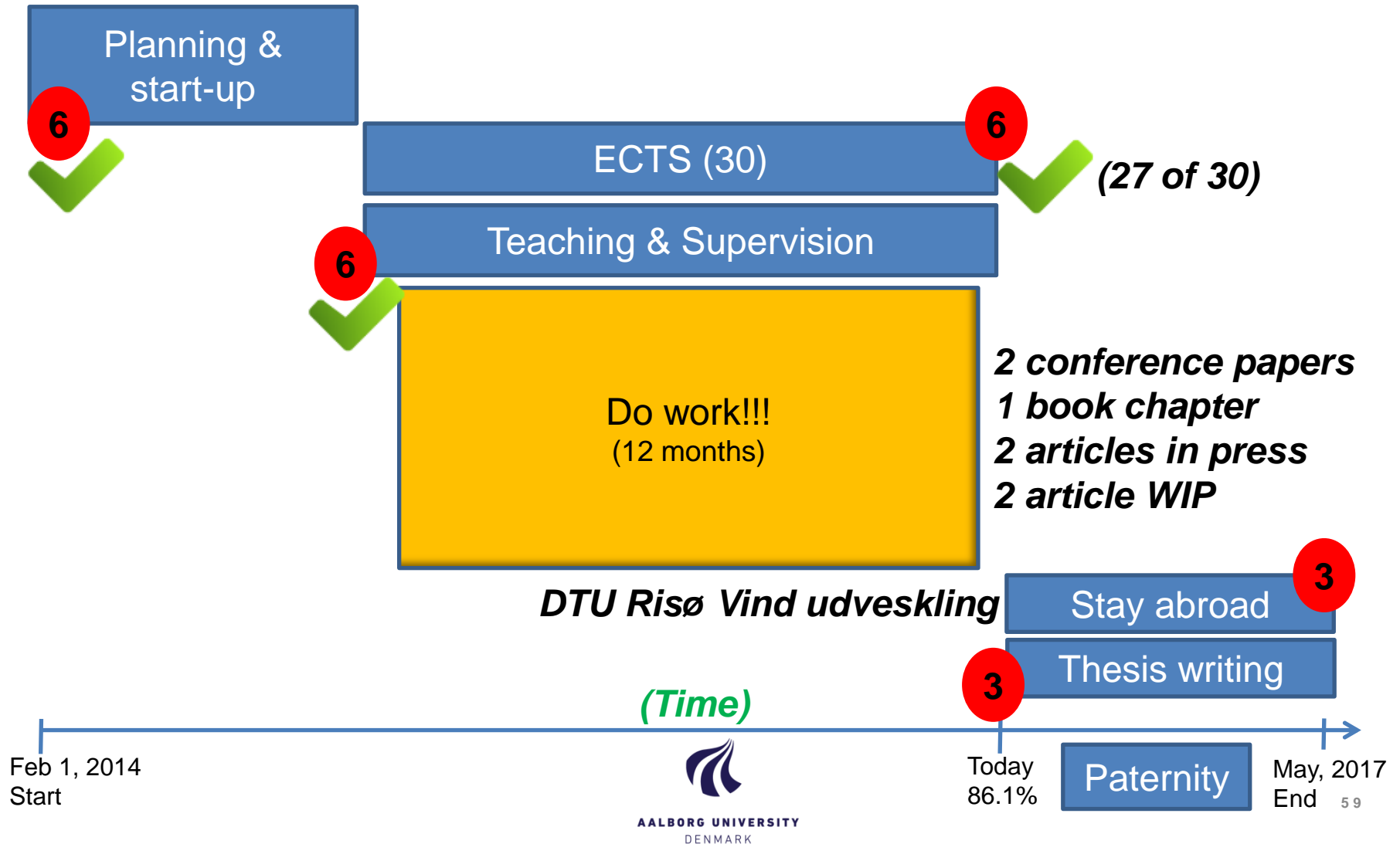


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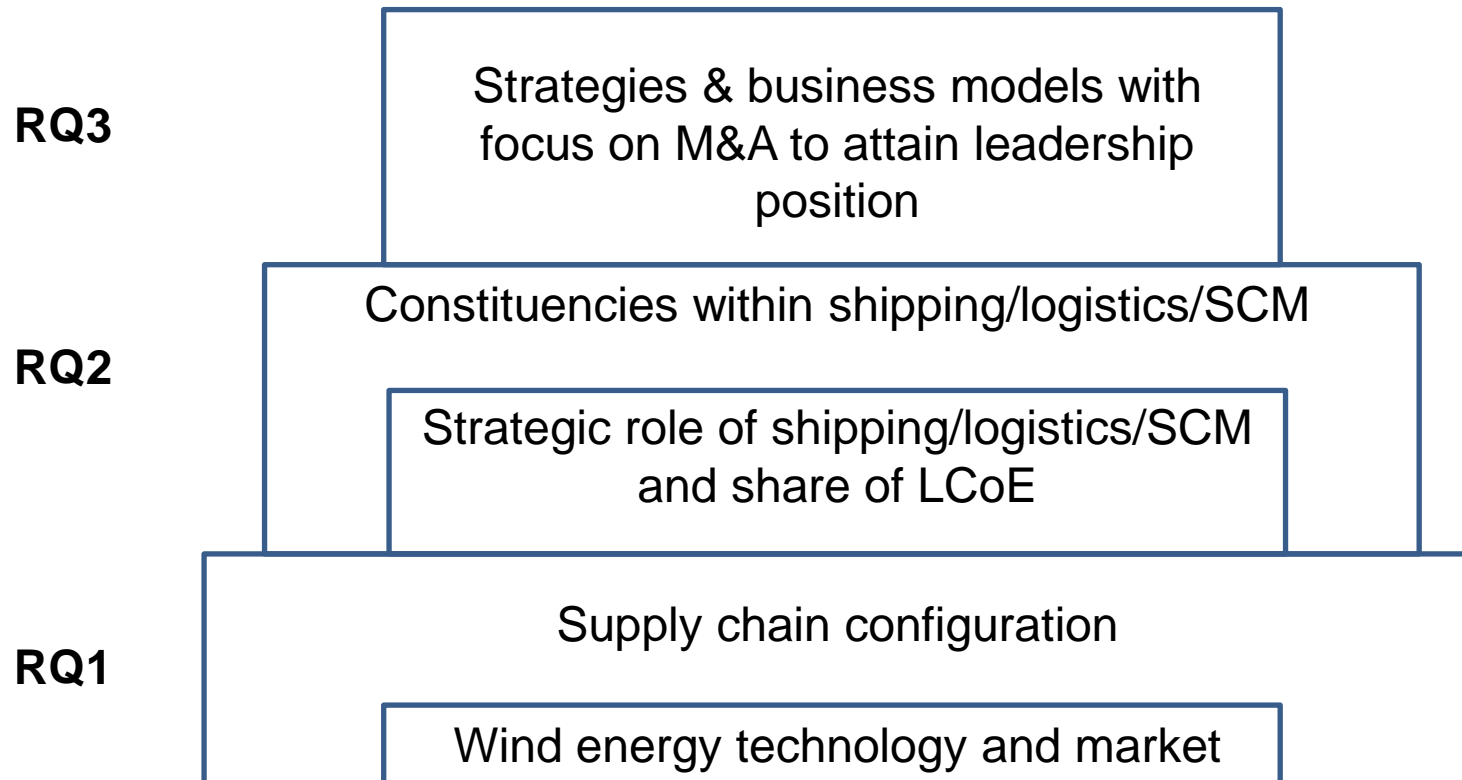


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Time blocks of Ph.d. (3 years)



Tiered research questions



PhD ECTS points required: 30

| <u>Kursus</u> | <u>Organizer</u> | <u>Timing</u> | <u>ECTS</u> | | <u>Extra ECTS</u> | | |
|---|------------------|----------------------|-------------|------------|-------------------|--|----|
| Introduction to the PhD study | AAU AAL | Spring, 2014 | 1 | | | | |
| EDSI doctoral consortium | EDSI/SDU | June, 2014 | 1 | | | | |
| EDSI conference paper | EDSI/SDU | June, 2014 | 1 | | | | |
| EDSI conference paper presentation | EDSI/SDU | July, 2014 | 1 | | | | |
| Danish Maritime Days conference | Thomas Poulsen | October 10, 2014 | 3 | | | | |
| How to design and defend your PhD | EIASM/EDEN | October 13-17, 2014 | 4 | | | | |
| Philosophy of Science | AU | January 26-29, 2015 | 4 | Plus Essay | 0 | | |
| Qualitative methods | RUC | March 5-6, 2015 | 2 | Plus Essay | 1 | | |
| Mergers & Acquisitions | EIASM/EDEN | March 23-27, 2015 | 4 | | | | |
| Synergies, conflicts, and trade-offs in climate change planning | AAU CPH | February 16-19, 2016 | 5 | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | 26 | | 1 | | |
| | | | | | | | |
| Grand total | | | | | | | 27 |

Content view of papers

EDSI peer reviewed book chapter published 2015:
Subsidized market, government created, derived market of logistics, M&A

Submitted journal manuscript with Lema: Analysis across all case studies

Case #1:
DONG Energy Wind Power
offshore wind logistics
innovation, LCoE, and
organization
Published Energies 2016

Case #2:
Offshoreenergy.dk
"Cost Reduction Forum"
Manuscript on Group 4 O&M
logistics W-I-P

Case #3:
China offshore wind
Gap analysis as of end 2015
Manuscript perhaps to be
written

Second peer reviewed conference paper/presentation EAWE 2013:
Life-cycle case study "test" – Anholt OWF

Initial peer reviewed conference paper/presentation LogMS 2013:
Life-cycles, exploratory, and industry practitioner challenges

The theoretical contribution! Published in IJESM 2016:
With Ram Narasimhan "Wheel of SCM" OW LCoE

Status

| | |
|--|-----------|
| 1. Conference paper LogMS 2013 | ✓ |
| 2. Conference paper EAWE 2013 | ✓ |
| 3. Peer reviewed book chapter 2015 | ✓ |
| 4. Peer reviewed article IJESM special issue April 2016 | ✓ |
| 5. Peer reviewed article DONG Energy (with DTU Wind Energy) | ✓ |
| 6. Manuscript Rasmus Lema | Submitted |
| 7. O&M paper | WIP |
| 8. China paper | ? |
| 9. Thesis | WIP |

Final thesis ToC

- Summary
- Introduction and background
 - ✓ Status of knowledge indicating scientific context
- Theoretical framework
 - ✓ Different per article
- Methodology
 - ✓ Flyvbjerg on misunderstandings about case studies

Final thesis ToC (cont)

- Short summary of each article
 - ✓ Incl. "rød tråd" and rationale/"fit"
- Results seen as a whole
 - ✓ Across individual journal articles
 - ✓ Compared to the 3 research questions (5 tiers)
- Conclusion
- References

Wrap-up and close



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Closing of today

- Date for next meeting
- Hosting company
- City

✓Wrap-up

Next Reference Group meeting

Date suggestion: March, 2017

Any volunteers?

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16:00-18:00 “Gå-hjem” meeting

Transfer to gå-hjem

***Now let us proceed to the
gå-hjem meeting / "go-home"
after work meeting***

UPSTAIRS