Wind Mussel Farm Simulation

a model to study synergy effects of combining offshore wind energy and large-scale mussel farming

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Founder of the AMC Research Foundation and AMC Centre Program Director
john.stavenuiter@amccentre.nl , 2014

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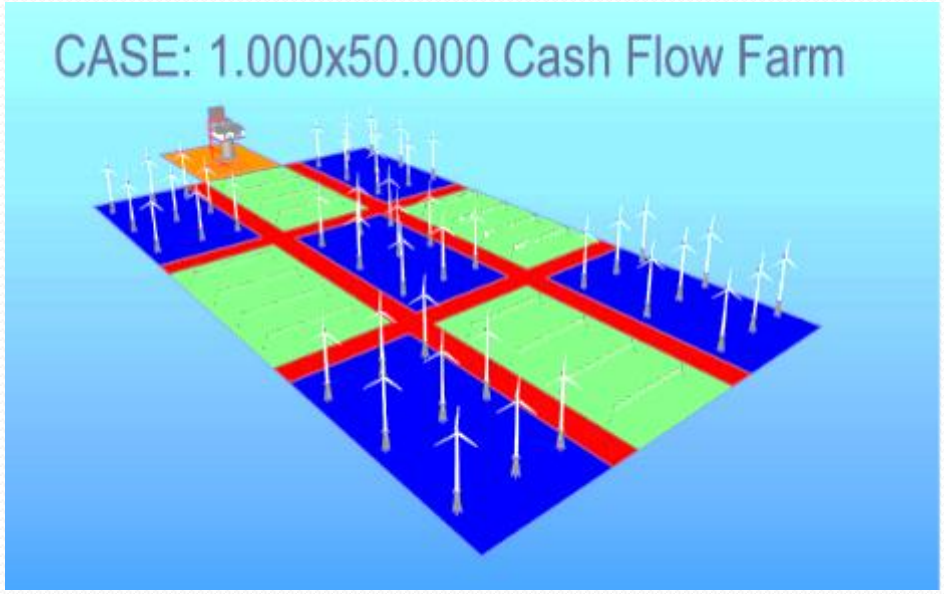
The Wind Mussel Farm
as initiated by the Blauwdruk project



- 200 MW Wind Turbine Clusters
- 12.500 ton Mussel Farming Clusters
- Electrical Grid & Distribution System
- Shipping Lanes

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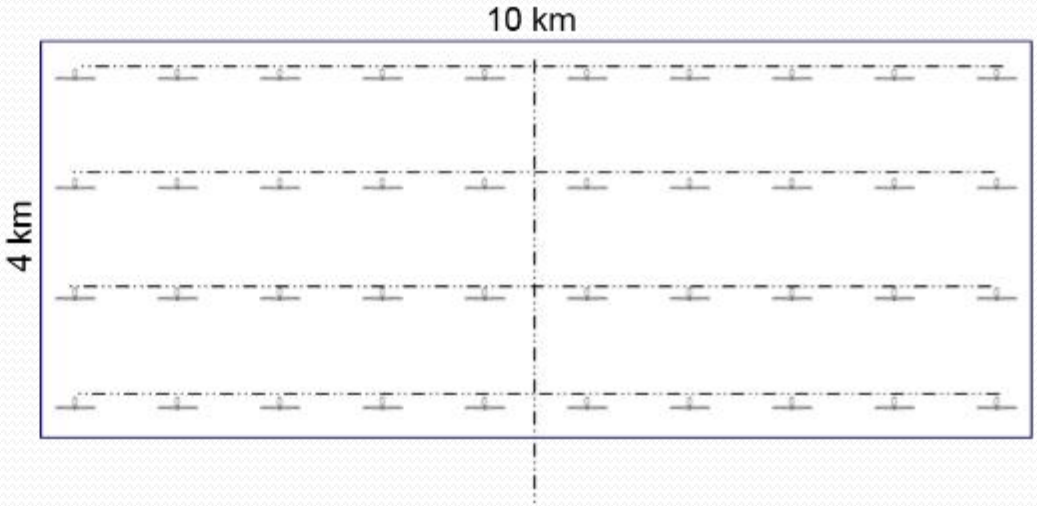
Wind Farm Outline incl. Auxiliary Systems

5 x 40 5MW
Wind Turbine
Incl. Foundation

~ 5 x 50 km
Wind Farm Grid
Subsea Cable

1x Wind Farm
Sub Station

4 x Wind Farm
Meteo and Nav.
Mast



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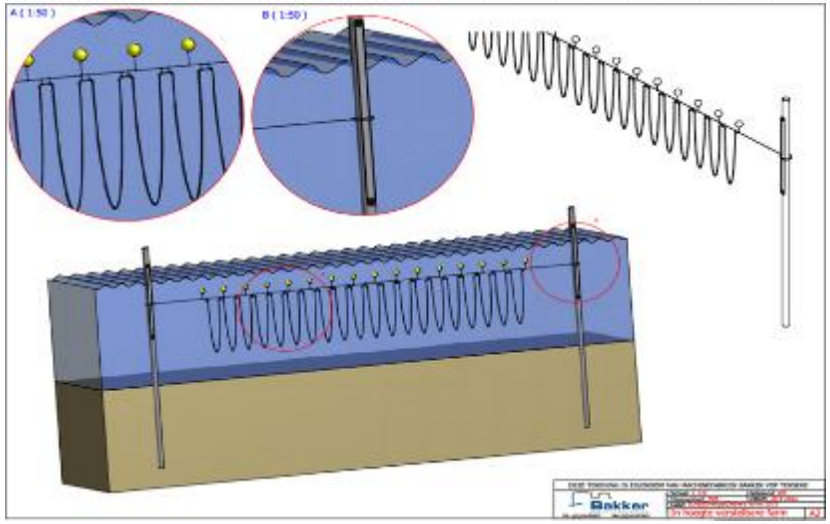
Mussel Farm Cluster Outline

The Mussel Farm Cluster exists of:

- 1.800 mussel long line systems of 100m long placed in lines of 4 km
- 150 m minimum wide of shipping lanes between the lines
- 8-15 tons production of mussel per system per year
- 12.000-25.000 tons production per cluster per year

→



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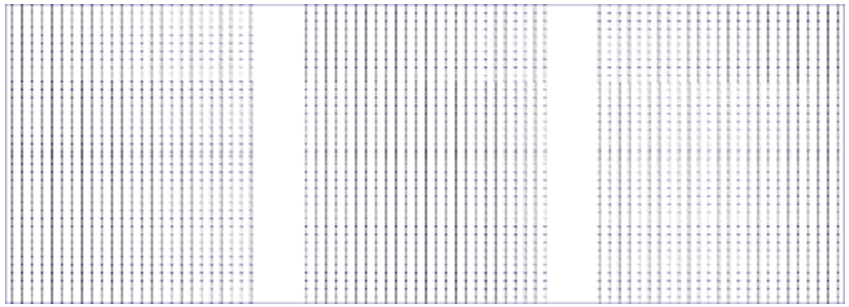
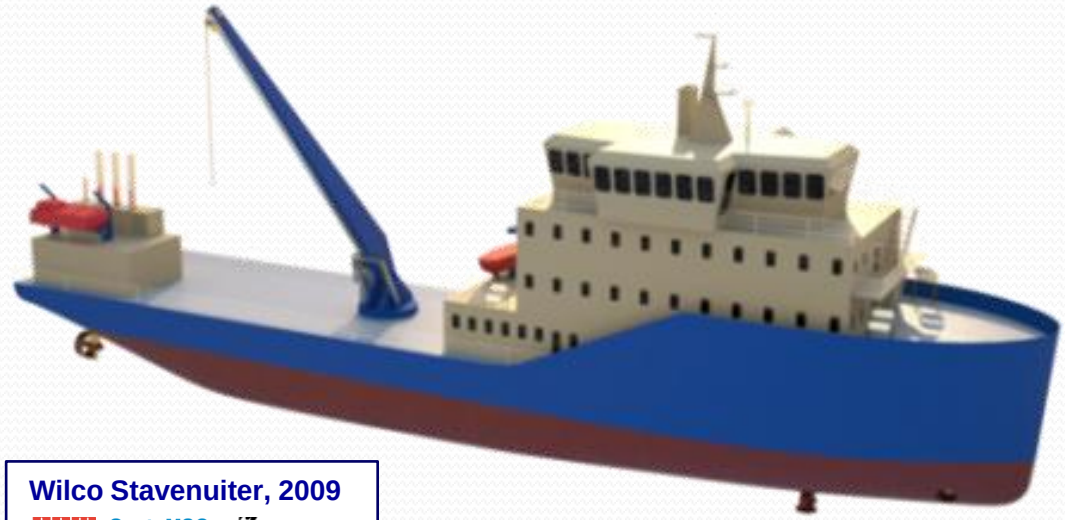


Wind Mussel Farming Support Ship

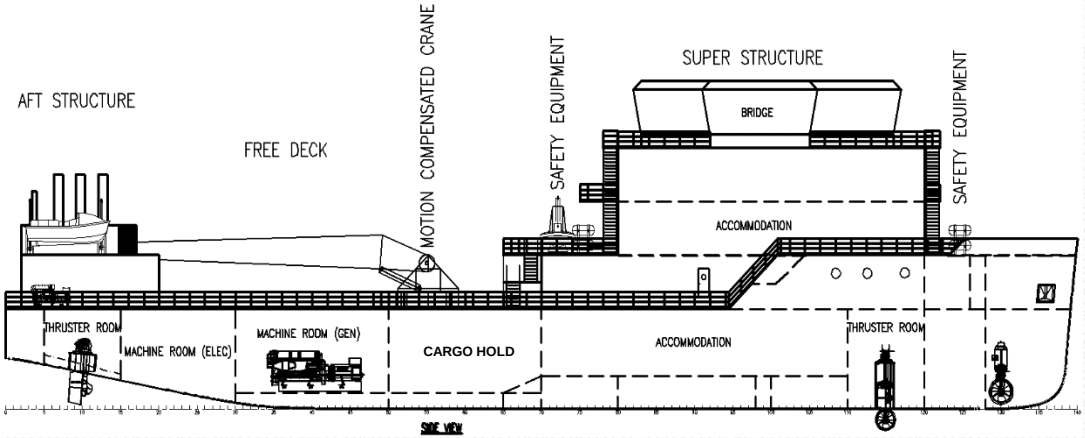
Main Dimensions	Symbol	Value	Unit
Length	Lpp	66.69	m
Length over all	LOA	70.00	m
Molded breadth	B	13.20	m
Least molded depth	D	6.00	m
Mean operating draught	T	3.44	m
Displacement	Δ	2365	m3
Block coefficient	Cb	0.78	-

Motion Compensated Crane	
Boom length	26.0m
Operating luff angle	60°
Max motion compensated lift	3 t @ all
Max non-motion compensated lift	13t @ 13m
Overall Mass	22 t
Installed Power pack	2*200 kW
Construction	Aluminum/Steel



Wilco Stavenuiter, 2009

SBM OFFSHORE GustoMSC TU Delft



Deck load: 12x20 ft. containers (Tools & Spares)

Accommodation: 50 persons.
The accommodation is applied with as much as possible double cabins to improve the comfort when the accommodation is not completely filled. Dimensioning of the accommodation is guided by the SBM accommodation standard and the NMD and ILO C133 code. At least it should comply with SOLAS.
Cargo Hold : 600 ton (fish/mussel)
Estimations: CAPEX: 20-30 M€, OPEX: 2,5 M€

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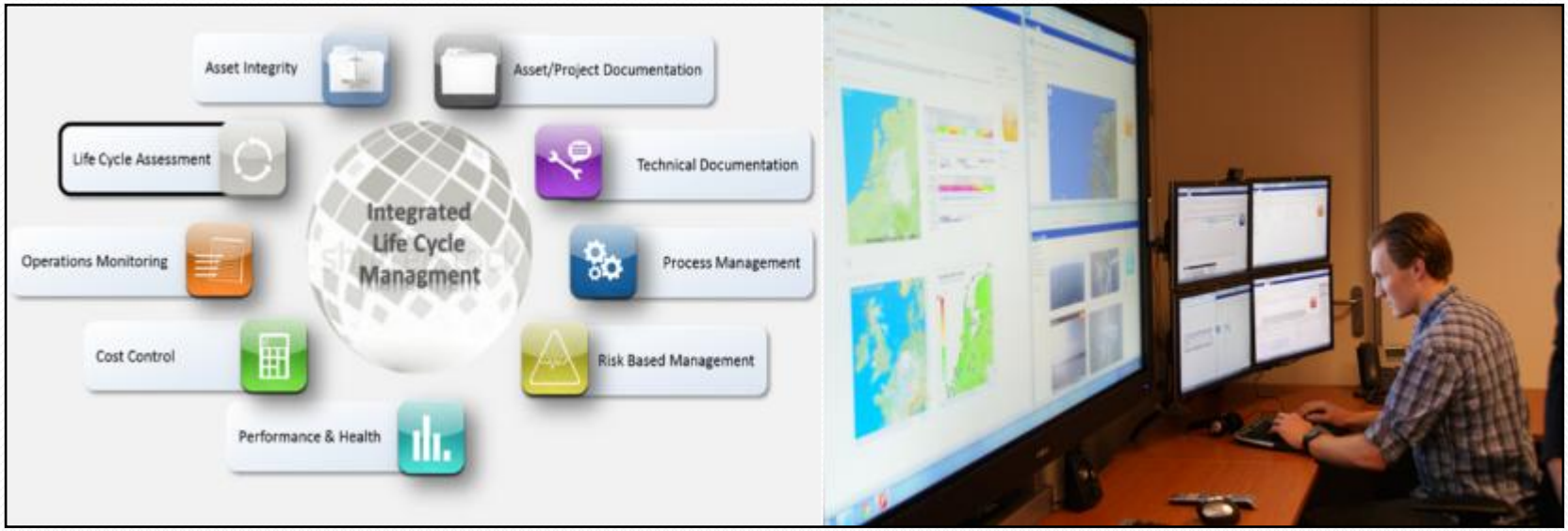
Mussel Harvest Subsystem (to be developed)

Some examples of existing systems

Estimated Cost (price level 2014)	CAPEX (10 yr. depr.)	OPEX (anual)
Special equipment used in combination with MC Crane	€ 350.000,-	€ 30.000,-

O&M Management System



The O&M Management System and - Process will be defined and estimated as part of the Year Scenarios.
The OPEX (including the depreciation on CAPEX) is estimated on 10 to 20 m€ per year, depending on the O&M strategy.

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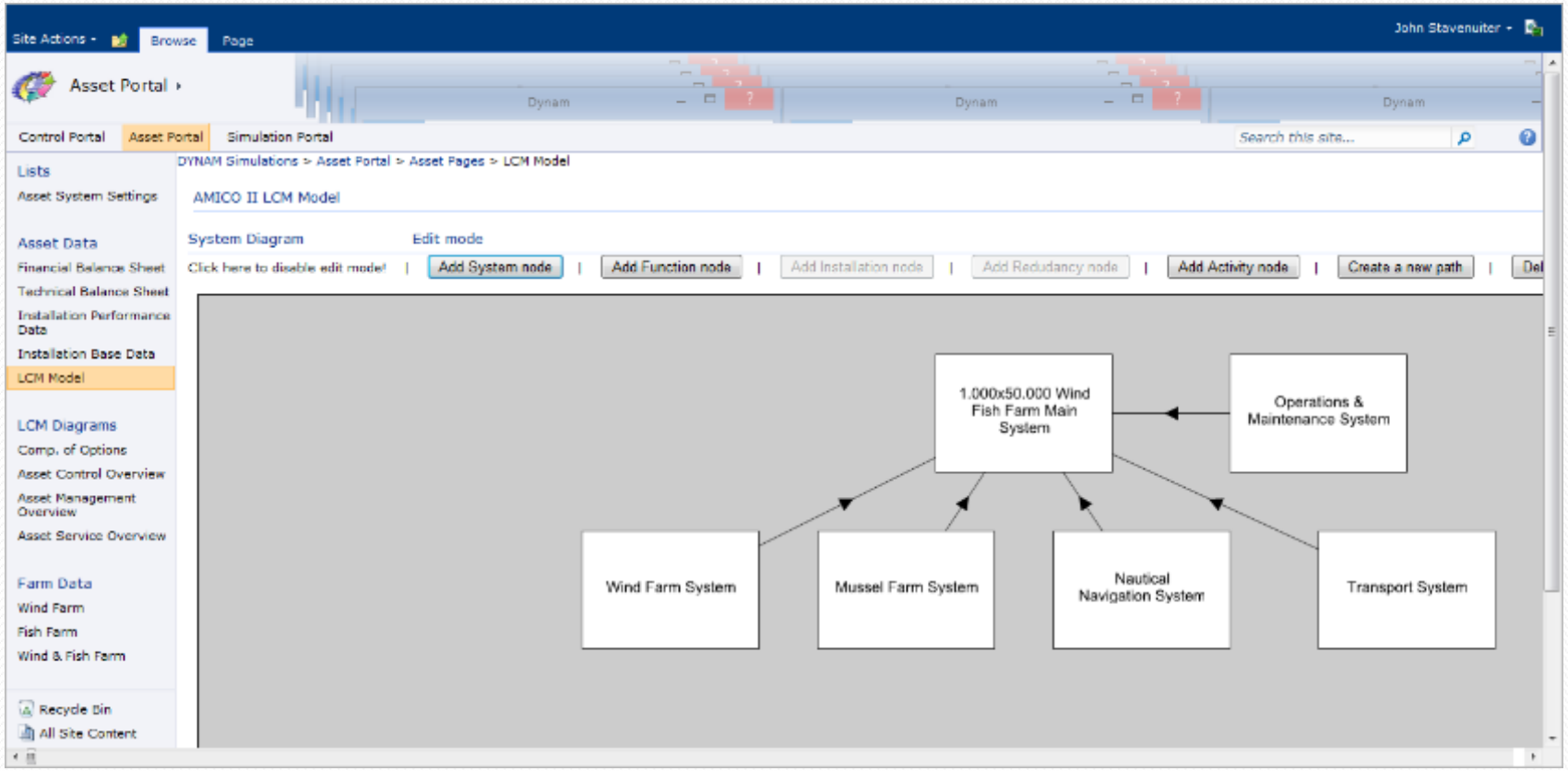
Modeling System of Systems



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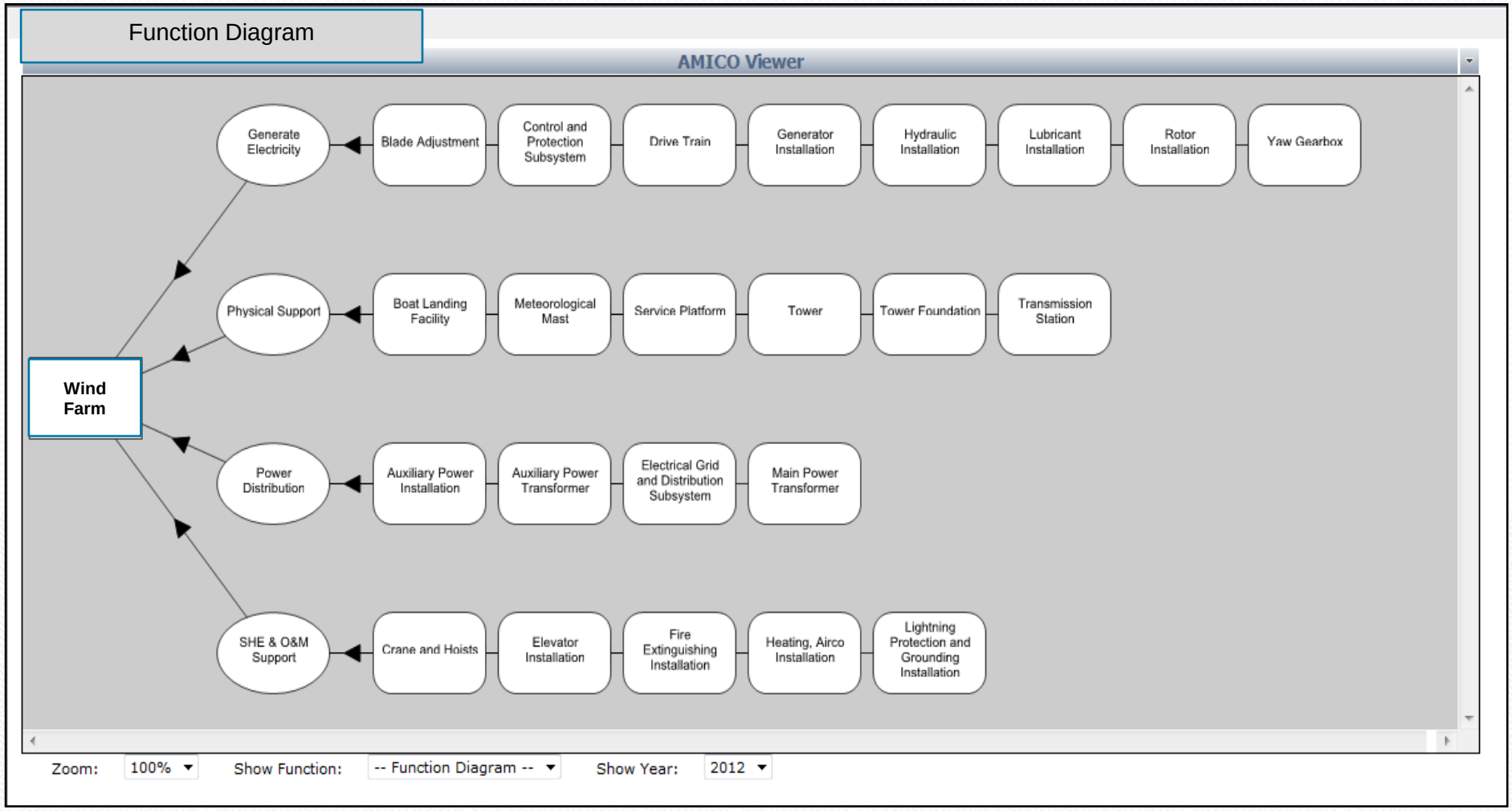
Modeling the System Structure



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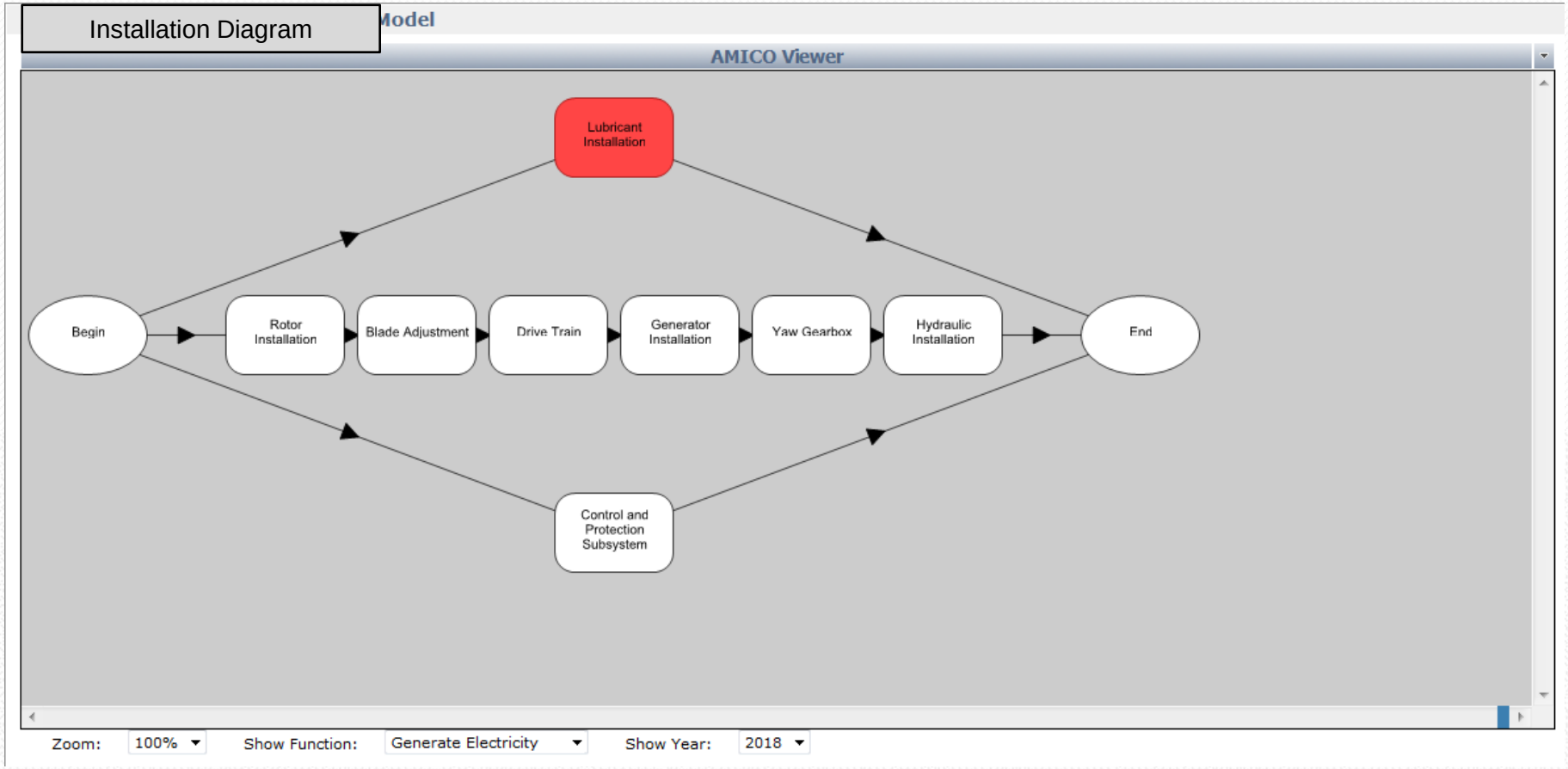
Modeling the Installation Block Diagrams



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Building Blocks
Attribute List
Frequently Asked Questions

Simulation Settings
Trend Settings
System Configurations
Year Scenario Control

Simulation History
Compare Sessions

Simulation Run
LCM Year Plan

Recycle Bin
All Site Content

- Scenario 1
- Base Scenario
- Blauwdruk Base O&M
- Base Refit and Overhaul

New | Edit | Copy | Delete

Scenario Overview

Save Scenario | Next

Title O&M Year Scenario:	Blauwdruk Base O&M
Version ID *:	BB O&M 1.0 Short Version Code
Name Initiator:	John Stavenuiter
E-mail Initiator:	john.stavenuiter@amccentre.nl
Location:	North Sea
Location Category:	5 DYNAM Scale
Use Profile:	Far Offshore
Use Profile Category:	1B IEC 61400-1 Scale
Top 2 Benefits/Features, 1:	Average Approach as determined by the OEM-ers
2:	Proven Technology and Processing
Effect on Active Time:	+/- | Indication with respect to the Initial Year Scenario (Base O&M)
Effect on Availability (in AT):	+/- | Indication with respect to the Initial Year Scenario (Base O&M)
Effect on Market Value:	+/- | Indication with respect to the Initial Year Scenario (Base O&M)
Effect on Management Control:	+/- | Indication with respect to the Initial Year Scenario (Base O&M)
Effect on Operation Excellence:	+/- | Indication with respect to the Initial Year Scenario (Base O&M)
Effect Revenues:	+/- | Indication with respect to the Initial Year Scenario (Base O&M)
Effect on Reliability:	+/- | Indication with respect to the Initial Year Scenario (Base O&M)
Aimed Synergy Percentage:	10 %
Active Time Wind Farm:	360 Days
Active Time Mussel Farm:	340 Days
Linked to System Configuration:	Blauwdruk Chash Flow Farm

Asset/System Related Cost differentiated to O&M Disciplines

Life Cycle Management Total Annual Cost (Services):	6500 k€

Scenario Overview

Previous | Save Changes

	MAMC (ISR in k€)	AT (day)	MTBF (yr)	IDF (%)	DLF (nr)	ELF (nr)	OLF (nr)	MTTR (day)
1. Onshore O&M Mgt Office	300	365	1	2.5	1	1	1	2
2. ERP/AMI IT-system (DOWES)	450	365	1	2.5	1	1	1	2
3. SCADA+ Control and Protection Subsystem (CPS)	750	365	1	2.5	1	1	1	2
4. Tower Foundation	1500	365	20	2.5	1	1	1	30
5. Tower & Nacelle	4800	365	20	2.5	1	1	1	30
6. Yaw Gearbox	3000	360	5	2.5	1	1	1	30
7. Rotor Installation	12900	360	5	2.5	1	1	1	20
8. Blade Adjustment	3000	360	5	2.5	1	1	1	10
9. Drive Train	3000	360	5	2.5	1	1	1	10
10. Generator Installation	6600	360	5	2.5	1	1	1	10
11. Main Power Transformer	1200	360	5	2.5	1	1	1	10
12. Auxiliary Power Transformer	2400	365	5	2.5	1	1	1	10
13. Auxiliary Power Installation (400-110V)	900	365	5	2.5	1	1	1	5
14. Hydraulic Installation	600	360	5	2.5	1	1	1	5
15. Lubricant Installation	600	360	5	2.5	1	1	1	5
16. Heating, Airco Installation	900	365	5	2.5	1	1	1	5
17. Fire extinguishing Installation	900	365	10	2.5	1	1	1	5
18. Lightning Protection and Grounding Installation	900	365	10	2.5	1	1	1	5
19. Elevator Installation	900	365	10	2.5	1	1	1	5
20. Crane and Hoists	900	360	10	2.5	1	1	1	5
21. Service Platform	900	365	10	2.5	1	1	1	5
22. Boat Landing Facility	600	365	10	2.5	1	1	1	5
23. Transmission Station (TS)	600	360	10	2.5	1	1	1	10
24. Internal 10-233 MW subsea power cables (Elec Grid)	2625	365	10	2.5	1	1	1	10
25. End piles	900	365	10	5	1	1	1	5
26. Long Lines	900	365	10	5	1	1	1	5
27. Mussel Socks	900	340	10	5	1	1	1	5
28. WFF Support Ship(s)	1250	360	0.5	2.5	1	1	1	3
29. Spare Part Containers	18	360	0.5	2.5	1	1	1	3
30. Mussel Harvest Subsystem	35	340	0.5	2.5	1	1	1	3
31. Subsea 1031 MW Power cable to Shore	556	365	10	2.5	1	1	1	20

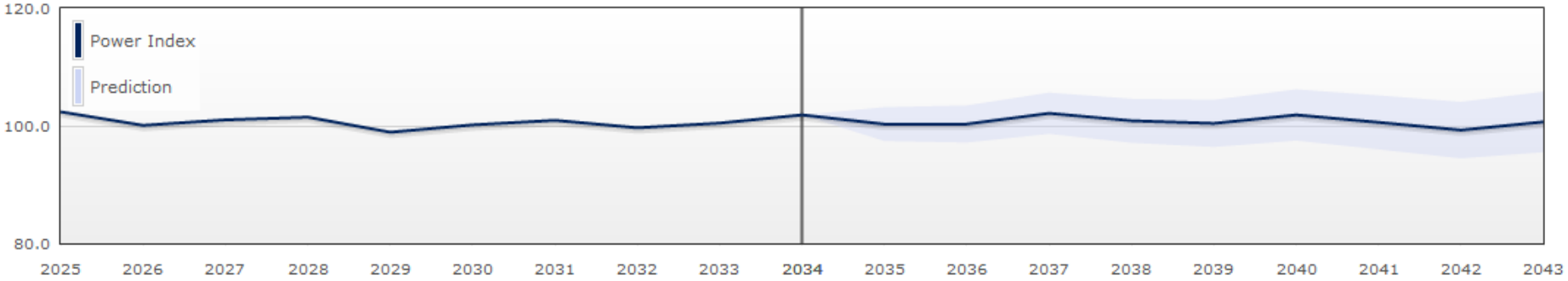
Analyst name:	Daniel	**Date:**	12/11/2014
Name of session:		**Configuration name:**	Blauwdruk Chash Flow Farm
Description:			

Year 1:	Blauwdruk Base O&M	**Year 11:**	Blauwdruk Base O&M
Year 2:	Blauwdruk Base O&M	**Year 12:**	Base Refit and Overhaul
Year 3:	Blauwdruk Base O&M	**Year 13:**	Blauwdruk Base O&M
Year 4:	Blauwdruk Base O&M	**Year 14:**	Blauwdruk Base O&M
Year 5:	Blauwdruk Base O&M	**Year 15:**	Blauwdruk Base O&M
Year 6:	Base Refit and Overhaul	**Year 16:**	Blauwdruk Base O&M
Year 7:	Blauwdruk Base O&M	**Year 17:**	Blauwdruk Base O&M
Year 8:	Blauwdruk Base O&M	**Year 18:**	Base Refit and Overhaul
Year 9:	Blauwdruk Base O&M	**Year 19:**	Blauwdruk Base O&M
Year 10:	Blauwdruk Base O&M	**Year 20:**	Blauwdruk Base O&M

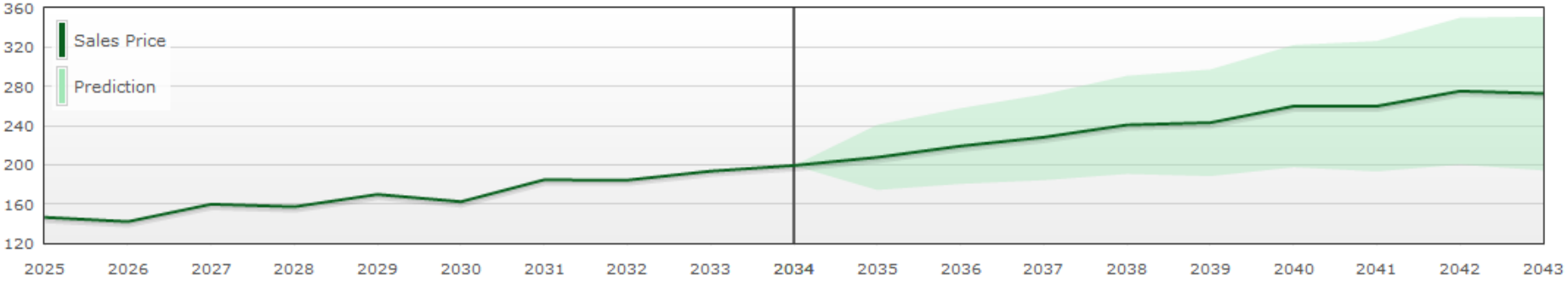
Situational Awareness Settings:		
Fixed Calculations:	☑ **When this is marked, the random factors related to 'ups and downs' in business are disabled.**	
Operational Excellence Factor (OEF) Settings:		
Operational Excellence Upper Limit Factor (OEULF):	0.2	**Nr.**
Max Operational Excellence Upper Limit (MxOEUL):	2	**Nr.**
Operational Excellence Lower Limit Factor (OELLF):	0.2	**Nr.**
Min Operational Excellence Lower Limit (MnOELL):	4	**Nr.**
Management Control Factor (MCF) Settings:		
Maintenance Improvement Upper Limit (MIUL):	10	**Nr.**
Management Control Index Improvement Factor (MCIIF):	0.2	**Nr.**
Maintenance Shrinking Lower Limit (MSLL):	2	**Nr.**

Trend Diagrams

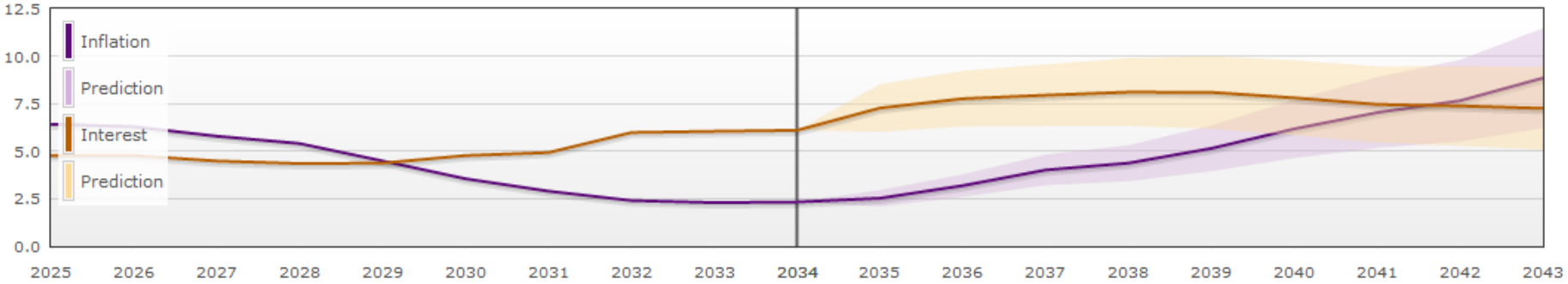
Wind Power Index(%)



Wind Power Sales Price(€/MWh)



Inflation & Interest(%)



Start simulations for *'Blauwdruk'*

	Prosperous economic developments and windfalls in business	Disappointed economic developments and setbacks in business
No Synergy	Nr 1 LCA	Nr 3 LCA
10% Synergy	Nr 2 LCA	Nr 4 LCA

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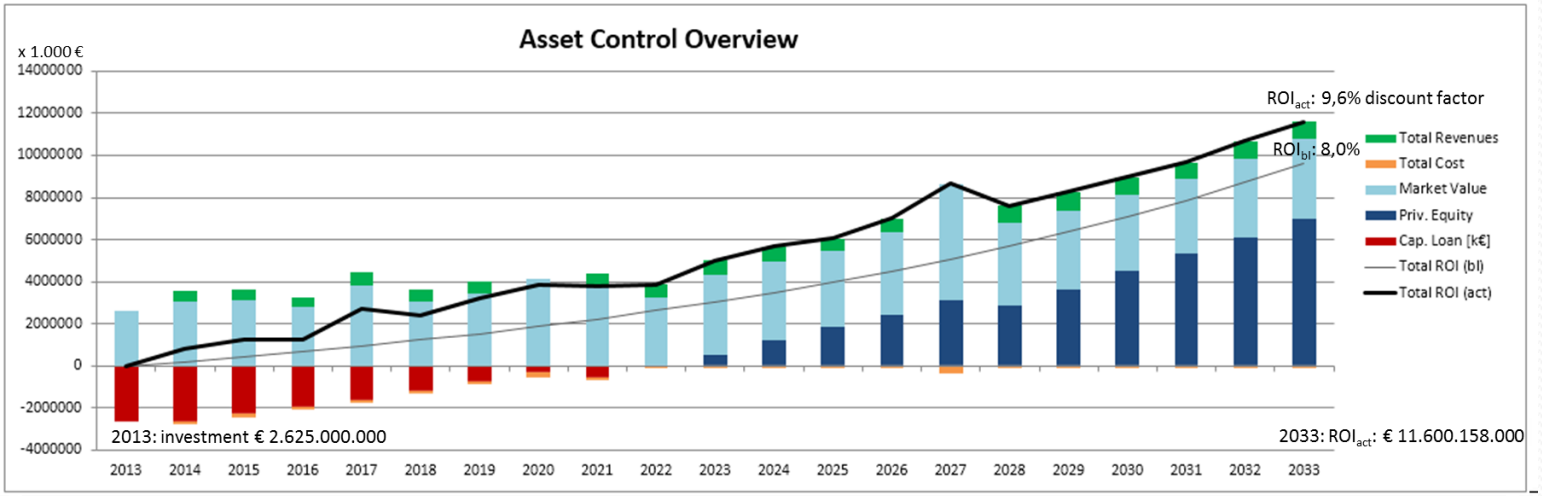
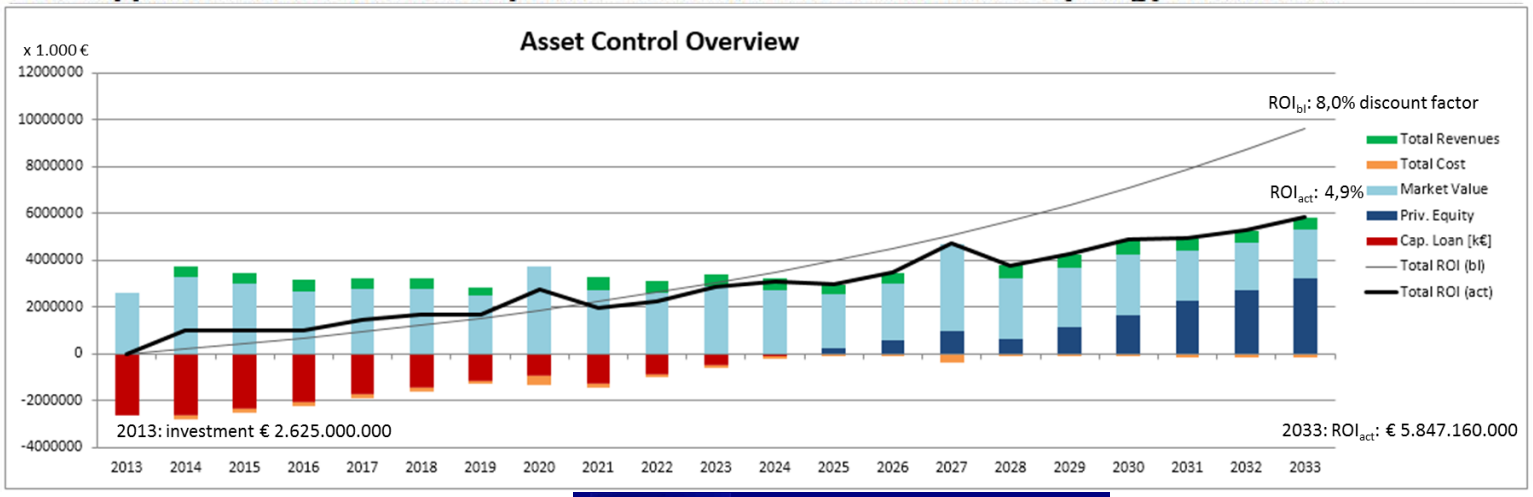
Results of simulation run 2 and 3

2: Prosperous economic developments and windfalls in business – synergy factor: 10%



3: Disappointed economic developments and setbacks in business – synergy factor: 0%



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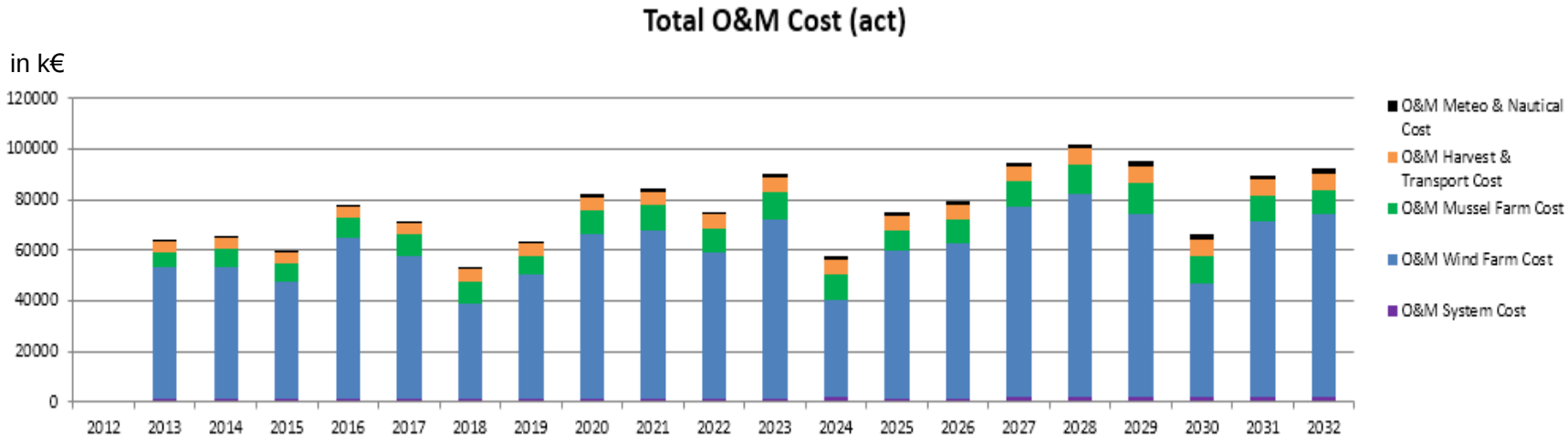
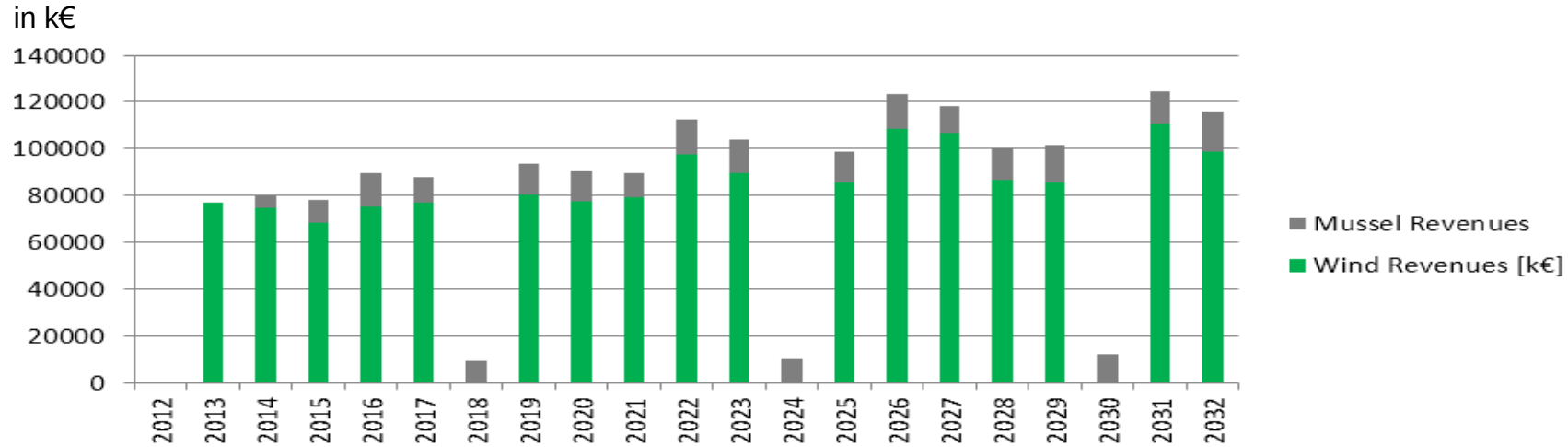
Cost vs Revenues (in depth analysis)





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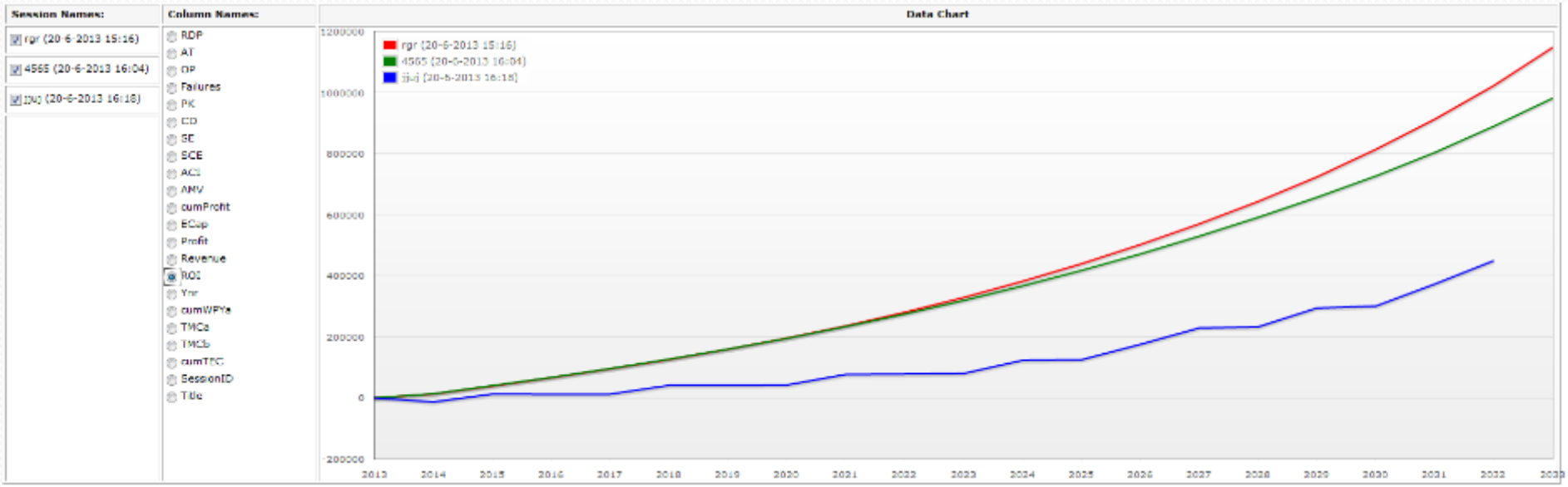
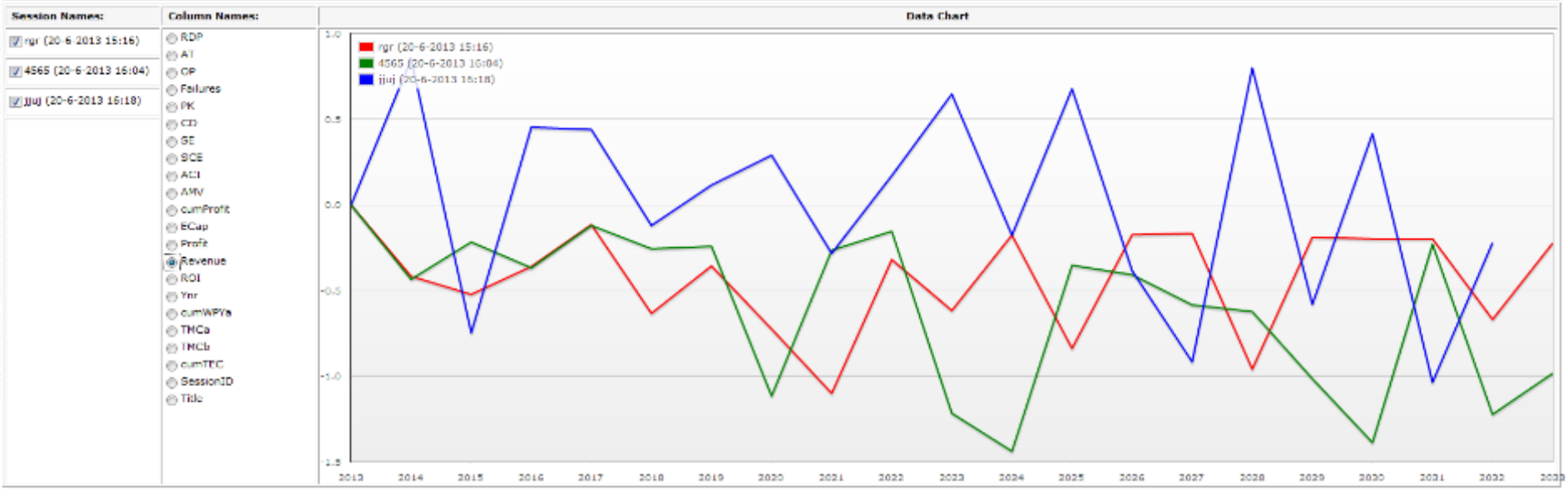
Comparing LCA Sessions





Conclusions & Evaluation

- Dynamic LCA Models could lead to a better understanding of system configurations
- Comparison of different outcomes helps the decision-making process
- Web based applications make the involvement of all stakeholders more attainable
- Whether this application ‘DYNAM’ is applicable in general, will be evaluated next year

Thanks for Your Attention

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