O&M strategies
A lifetime optimisation process

7th annual Wind Energy O&M Forum

René van de Pieterman
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ECN at a glance

Mission:
...To develop, with and for the market, knowledge and technologies that enable a transition to more sustainable energy systems.

Founded in **1955**
5 Commercial licensing deals p/y
600 Employees
+/-20 patents a year
€ 80 M annual turnover

ECN Focus Areas

Solar energy

Biomass

Policy studies

Energy efficiency

Wind energy

Environment & energy engineering

Innovative solutions
to lower the cost of energy

ECN

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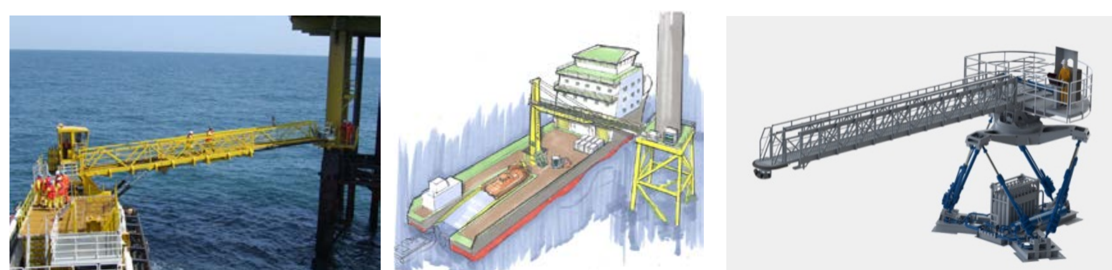
Introduction

Typical O&M concepts

- Near shore / smaller farms
  - Workboat for transfer of crew and small spare parts
  - Optional: helicopters for crew transfer
  - Heavy lift vessel for large component replacement
- Far-offshore / larger farms
  - Fixed base / Mother vessel?
  - Reduce travel time
  - Increase accessibility

Example of typical near shore maintenance strategy

Examples of offshore service vessels



Examples of compensated access gangways

O&M strategy – Planning Phase

Planning for successful O&M

Wind Farm Developers

- Find the optimal O&M strategy for a given wind farm
- Quantify O&M costs and risks for project financing
- Selection of vessels and equipment
- Verify O&M quotations from OEM's and discuss starting points

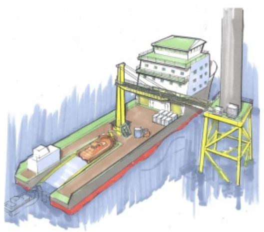
Turbine Manufacturers

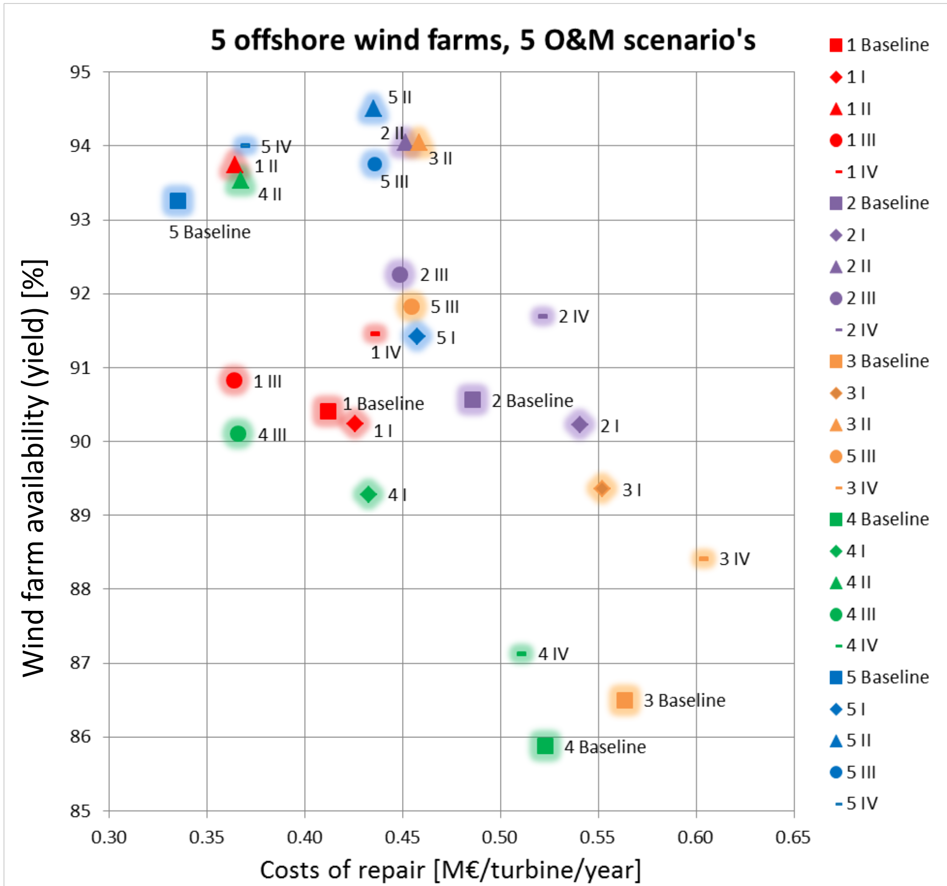
- Improve design from reliability and maintainability of design
- Prepare O&M strategy and quotations for clients

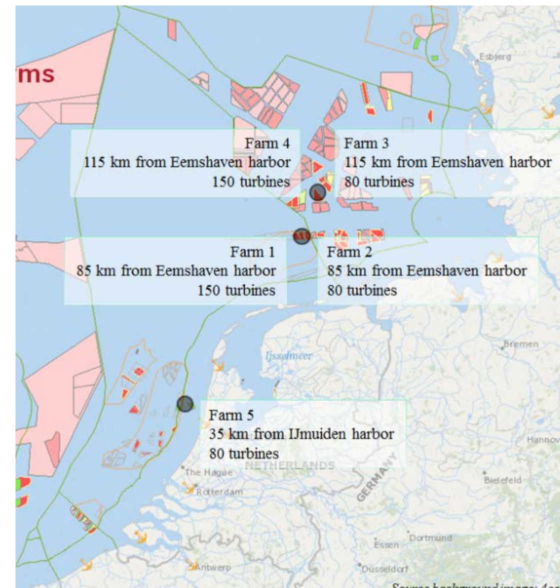
Vessel and access system developers

- Quantify the effect of design assumptions
- Establish business case for new innovative solutions

Example




5 offshore wind farms, 5 O&M scenario's
Wind farm availability (yield) [%]
Costs of repair [M€/turbine/year]
95
94
93
92
91
90
89
88
87
86
85
0.30
0.35
0.40
0.45
0.50
0.55
0.60
0.65
5 II
2 II
3 II
5 IV
1 II
4 II
5 III
5 Baseline
2 III
5 III
2 IV
1 IV
5 I
1 III
1 Baseline
2 Baseline
1 I
2 I
4 III
4 I
3 I
3 IV
4 IV
3 Baseline
4 Baseline
1 Baseline
1 I
1 II
1 III
1 IV
2 Baseline
2 I
2 II
2 III
2 IV
3 Baseline
3 I
3 II
5 III
3 IV
4 Baseline
4 I
4 II
4 III
4 IV
5 Baseline
5 I
5 II
5 III
5 IV


ms
Farm 4
115 km from Eemshaven harbor
150 turbines
Farm 3
115 km from Eemshaven harbor
80 turbines
Farm 1
85 km from Eemshaven harbor
150 turbines
Farm 2
85 km from Eemshaven harbor
80 turbines
Farm 5
35 km from IJmuiden harbor
80 turbines
Source background image: 4coffsh

O&M Optimisation – Operational Phase

The most important phase!

Predictive maintenance

- Avoid long unexpected downtimes
- Reduce costs by planning ahead and clustering

Make well-founded decisions

- Identify options for increasing production and reducing costs
- New O&M contracts, vessels and equipment
- Solid background for O&M budget
- Assist in planning predictive maintenance

Value of operational data: Example

- Inventory of O&M data for 3 month period of RWE's Rhyl Flats wind farm:
  - List of SCADA parameters
  - Alarm list
  - Meteo and wave data
  - Monthly downtime summary reports
  - Daily work reports
  - Turbine breakdown
  - Daily vessel reports
- Observations
  - Many different data sources stored independently and in different formats
  - ECN used supplied O&M data to manually structure and fill Event List format
  - Sufficient (92%) data available for data analysis

Start and definition of event

Event nr.		*1*	
Start event	[date/time]	15/02/2013 09:33	
Event type		Corrective maintenance	
Turbine ID or BOP ID		1. Turbine A	
Nr. maintenance action		*1.1*	*1.2*
Start	[date/time]	15/02/2013 09:33	16/02/2013 08:30
End		15/02/2013 14:33	16/02/2013 17:00
Duration	[h]	1.05	8.50
Downtime	[h]	5.00	8.50
Type of maintenance		Inspections	Replacement (finalisation)
Weather downtime	[h]	4.00	0.00
Scada alarm code		0001	0010
Scada description		Temperature error	Turbine stopped by operator
Reported labour hours	[h]	2.00	
Crew size		2	
Access equipment		Access vessel	
- travel time (heading out)	[h]	0.75	
- travel time (return)	[h]	1.00	
- fuel consumption	[dm^3]	200	225
Second equipment		n.a.	n.a.
- travel time (one way)	[h]		
- mobilisation time	[h]		
Third equipment		n.a.	n.a.
- travel time (one way)	[h]		
- mobilisation time	[h]		
Explanations		Pitch motor overheated	Replaced pitch drive blade A
Main system_ID		MDC Blade adjustment	
Component ID		GL001 Pitch drive assembly A	
Work carried out		*Replacement*	
Spare part in stock		Yes	
Logistic time spare part	[h]	2	
Consumables		n.a.	
# consumables			
Total labour hours	[h]	*27.50*	
End event		*16/02/2013 17:00*	
Duration event	[h]	*31.44*	
Downtime event	[h]	*31.44*	

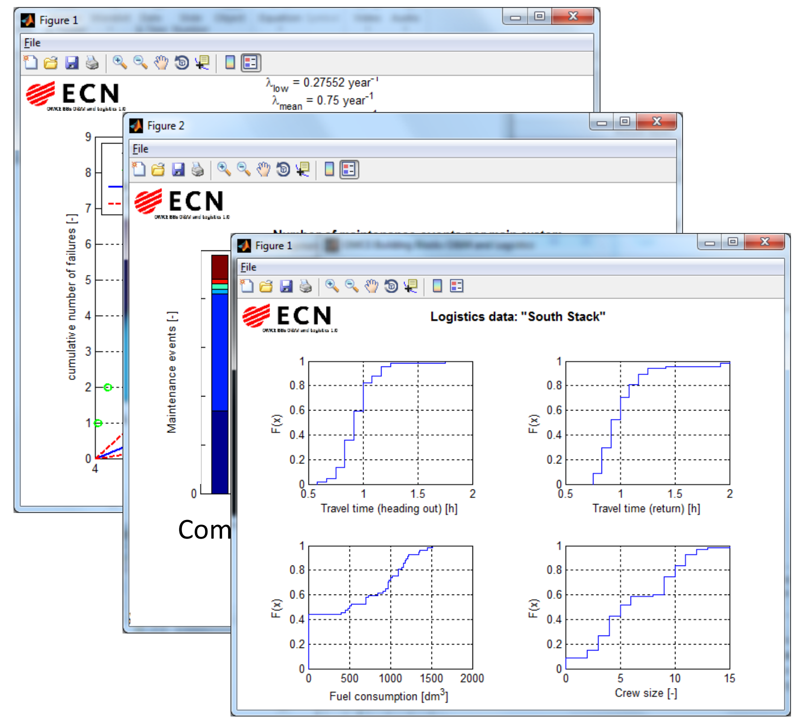
Definition of individual maintenance actions

End of event and reporting

Value of operational data: Key performance information

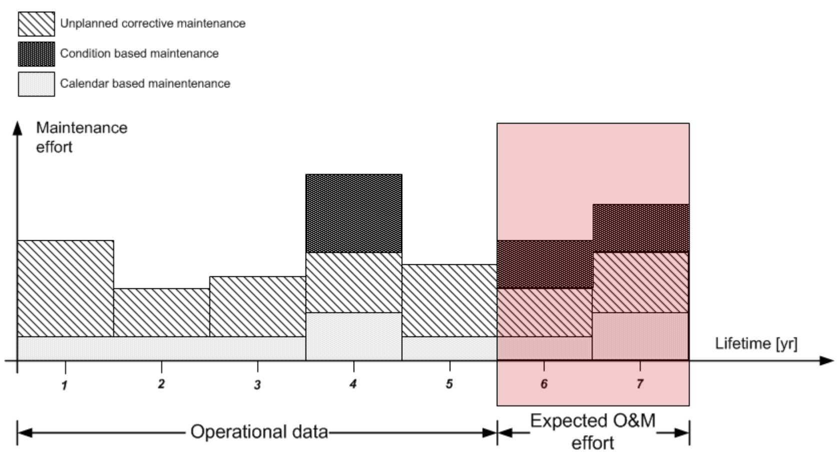
- Apply dedicated data analysis tools to obtain actual O&M performance:
  - Trends in failure behaviour
  - Insight in repairs
  - Details on spare part usage
  - Operation of vessels and equipment

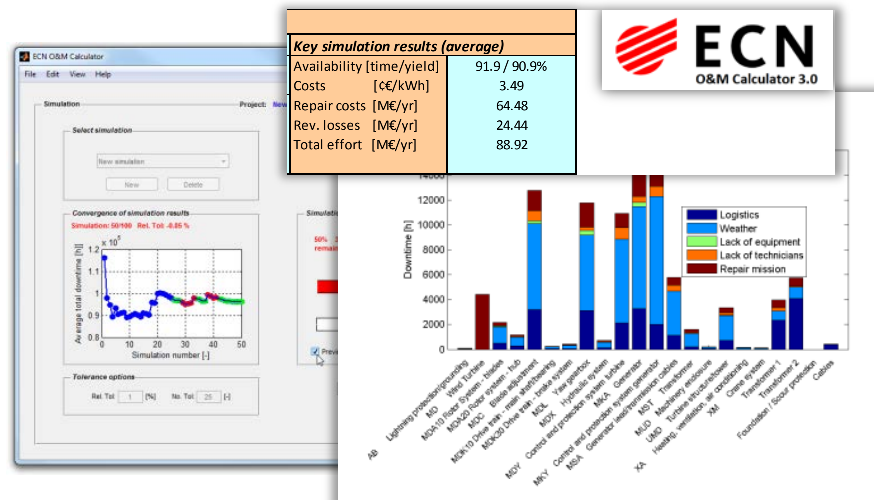
- Implement and evaluate improvement plans:
  - Is component reliability improving after solving teething issues?
  - Is the same repair performed quicker as more experience is gained?
  - Is my vessel and crew operating up to its designed limits?



Value of operational data: O&M cost modelling

- Reliable prediction O&M effort using O&M Calculator tool:
  - Based on accurate input derived from operational experience
- Well-founded decision making:
  - Identify options for increasing production and reducing costs
  - New O&M contracts, vessels and equipment
  - Solid background for O&M budget
  - Assist in planning predictive maintenance



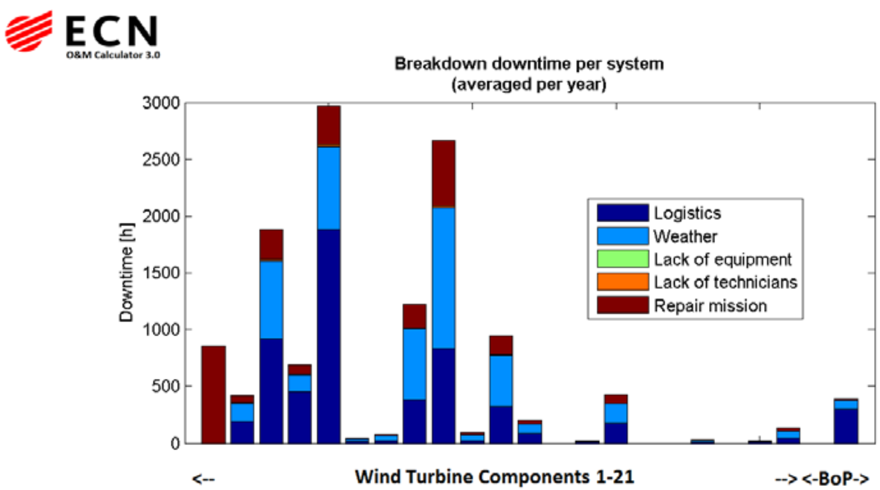


O&M Optimisation – Case study

Case study Rhyl Flats wind farm

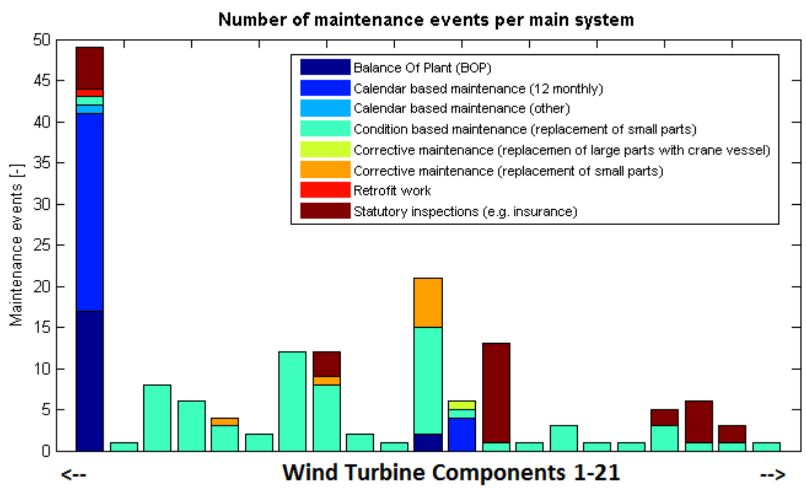
- Step 1: Reference calculation O&M costs
  - Based on historical data and assumptions

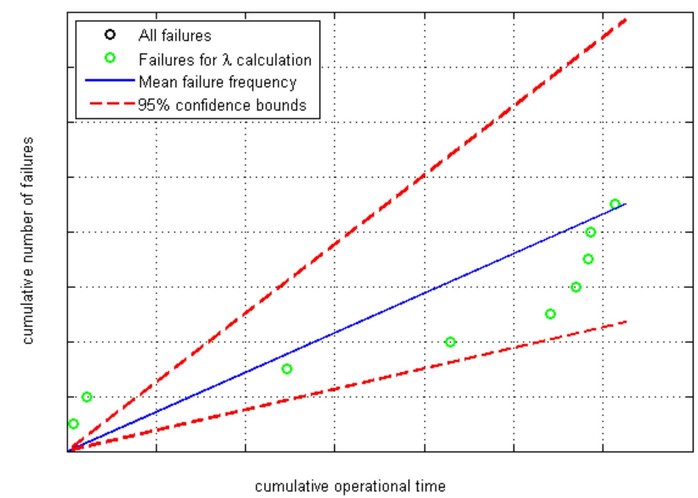
Summary of downtime & costs				
Project	**Rhyl Flats baseline**		***Key simulation results (average)***	
Installed wind farm capacity	90,0	MW	Availability [time/yield]	94 / 93.2%
Number of wind turbines in farm	25		Costs [c€/kWh]	4,52
Simulation	**sim**		Repair costs [M€/yr]	12,51
Simulation period	1	yr	Rev. losses [M€/yr]	2,63
Start-up period	1	yr	Total effort [M€/yr]	15,14
Number of simulations	1000			



Case study

- Step 2: Analysis operational data
  - 3 months of operational data
  - Derived estimated failure rates of components





Case study

- Step 3: Update calculation O&M costs
  - Based on updated input data (e.g. failure rates)

Summary of downtime & costs				
Project	**Rhyl Flats updated**		***Key simulation results (average)***	
Installed wind farm capacity	90,0	MW	Availability [time/yield]	96.2 / 95.8%
Number of wind turbines in farm	25		Costs [c€/kWh]	3,35
Simulation	**sim**		Repair costs [M€/yr]	9,52
Simulation period	1	yr	Rev. losses [M€/yr]	1,64
Start-up period	1	yr	Total effort [M€/yr]	11,16
Number of simulations	1000			

- Step 4: Implement O&M strategy improvements
  - Reduce number of available access vessels & technicians
  - Only perform preventive maintenance when wind speeds are below 4 m/s

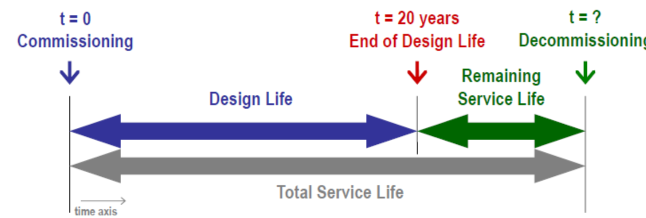
Summary of downtime & costs				
Project	**Rhyl Flats optimised**		***Key simulation results (average)***	
Installed wind farm capacity	90,0	MW	Availability [time/yield]	96.2 / 96%
Number of wind turbines in farm	25		Costs [c€/kWh]	3,00
Simulation	**sim**		Repair costs [M€/yr]	8,53
Simulation period	1	yr	Rev. losses [M€/yr]	1,57
Start-up period	1	yr	Total effort [M€/yr]	10,10
Number of simulations	1000			

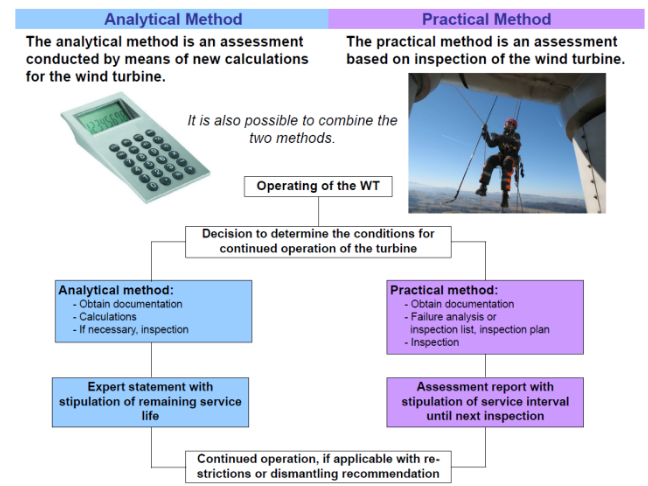
10% costs reduction
4% revenue increase

Lifetime extension

Lifetime extension

- Offshore wind farms are designed for a 20 year lifetime
- Load case calculations play an important role in the design
- Sizeable safety factors are considered for structural components
- How long can we continue?





Approaching design lifetime...

Keep track of O&M performance

- Consider service history
- Evaluate trends in failure behaviour
- Decide on remaining economic lifetime

Evaluate wind farm load history

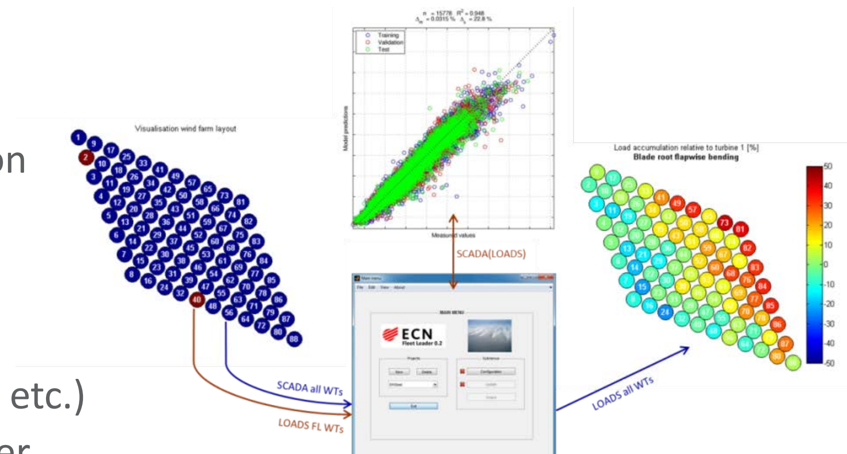
- Relative comparison between turbines
- Comparison actual loads with design loads (when available)
- Can be done based on a short-term measurement campaign!

Wind Farm Load History

What measurements are required for a successful assessment?

- Mechanical load measurements
  - Blades and support structure
  - Campaign with one year minimum duration
  - On at least one turbine; preferably two

- SCADA data
  - Standard signals (e.g. power, speed, pitch, etc.)
  - 10-min statistics sufficient; 1 Hz even better
  - For the complete wind farm lifetime!
  - From all turbines!



Conclusions

Summary

- O&M optimisation is important during every phase of the lifetime
- Initial strategy set-up at planning phase using cost modelling tools
- Data analysis and cost modelling should be performed during the operational phase and will lead to reduce costs
- Operational history supported by load measurements and inspections will be required to evaluate remaining economic lifetime

Thank you very much for your attention

René van de Pieterman
Researcher Wind Energy
vandepieterman@ecn.nl
+31 88 515 4616