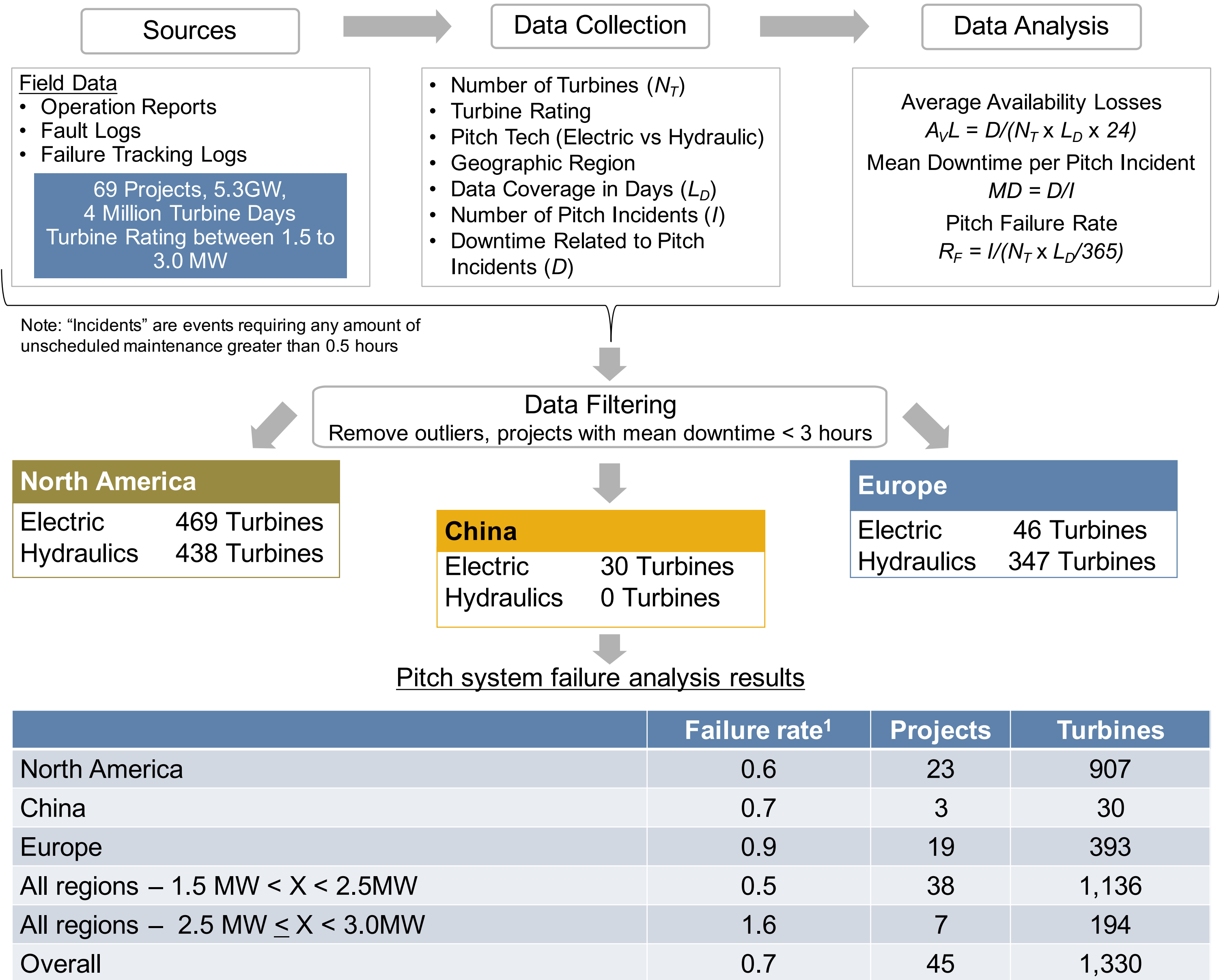


Introduction

- The Reliawind project identifies Pitch Systems as the #1 component contributing to turbine failure & downtime
-
- Pitch systems in a wind turbine represents:
 - Less than 3% of wind farm CAPEX investment (source: Moog, BNEF)
 - 20 to 30% of wind turbine O&M expenses (source: OEM interviews by Moog)
 - 21% of wind turbine failure rate and 23% of downtime (source: Reliawind)
 - Moog / DNV GL study confirms that *pitch system reliability improvements can save up to 12% of wind farms O&M expenses*

Moog – DNV GL research uses operational data to benchmark pitch system failure rate and its impact on LCoE



- ¹ Incidents per turbine per year from projects with mean downtime > 3 hours
- Pitch system reliability benchmarking study reconfirms that:
 - Pitch systems (electric & hydraulic) are a major failure component in a wind turbine
 - The larger the turbine, the greater the failure rate of pitch systems

Pitch technology comparison

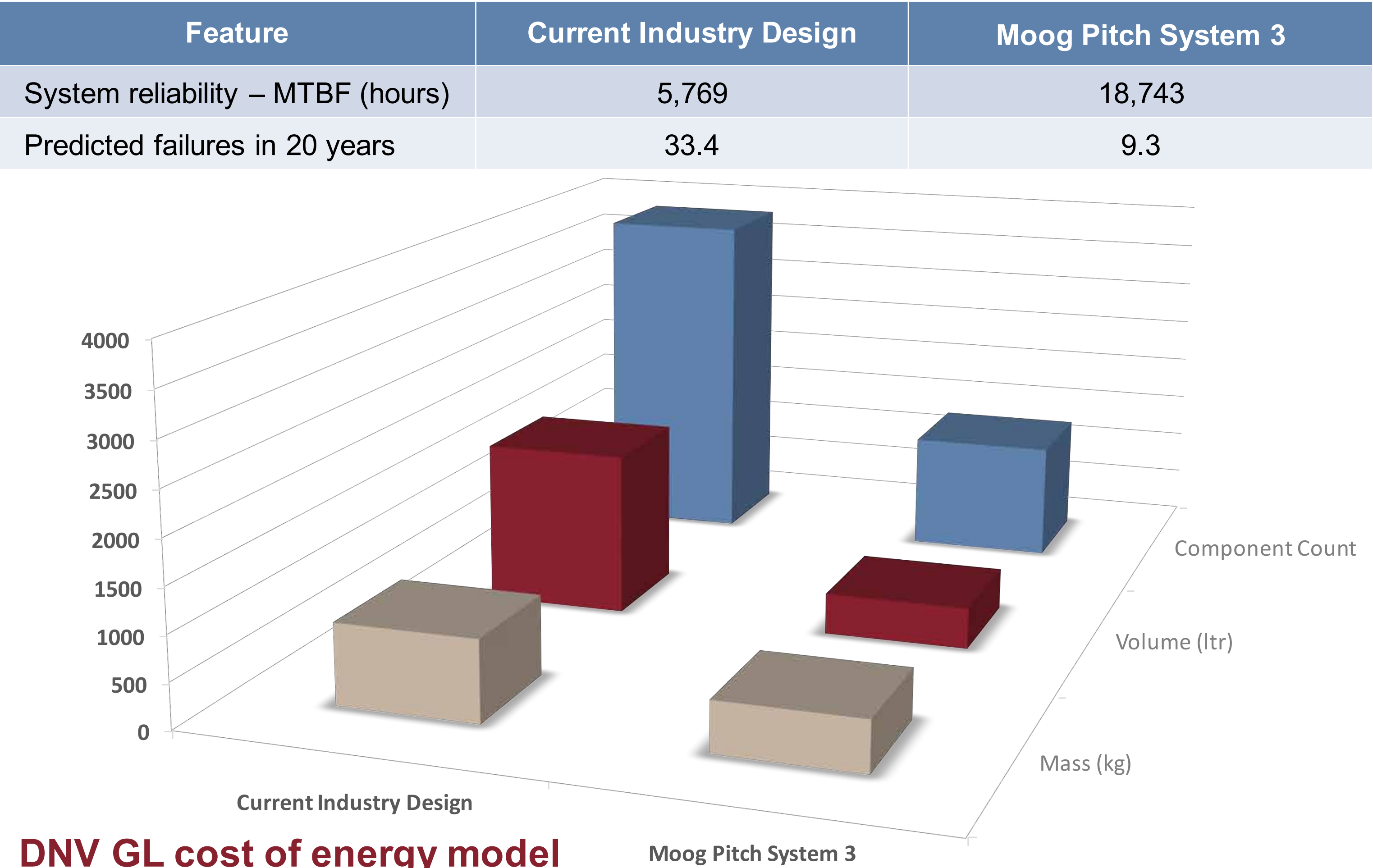
Moog evaluated the following technology options for pitch system reliability improvement

Technology Comparison

EMA	EH	EHA	Attribute	EM	EH	EHA
			Compactness (size, weight and reduced part count)	+++	+	++
			Design/Supply Chain Simplicity	+++	+	++
			Control Quality	+++	+	++
			Pre Tested Hardware	+++	+	++
			Force Range	++	+++	+++
			Ease of Maintenance	+++	+	++
			Reliability	+++	+	+
			Legend			
				+ Improvements from Next Generation Technology		
				+ Current Industry Design		

Design improvement analysis

- Moog Pitch System design optimization study confirms that:
 - There are limited or no options to improve pitch system reliability further with EH/EHA technology
 - EM offers significant potential for reliability improvement due to:
 - Pluggable (highly integrated) electronics design for drives
 - AC servo motor technology
 - Advances in ultra capacitors design
 - Tests validated by Moog using a new and improved pitch system design (Moog Pitch System 3) showed a significant improvement in reliability



DNV GL cost of energy model

- Using the findings of the benchmarking study as inputs, DNV GL carried out an analysis to calculate the LCoE to for the new Moog Pitch System 3 with an optimized design and high reliability
- The study made use of two DNV GL modeling tools (Turbine.Architect and OMCAM) to calculate CapEx, OpEx, and finally, LCoE based on pitch system reliability profiles provided by Moog

