Influence of Structural Design Effects on Economic Viability of Offshore Wind Turbines

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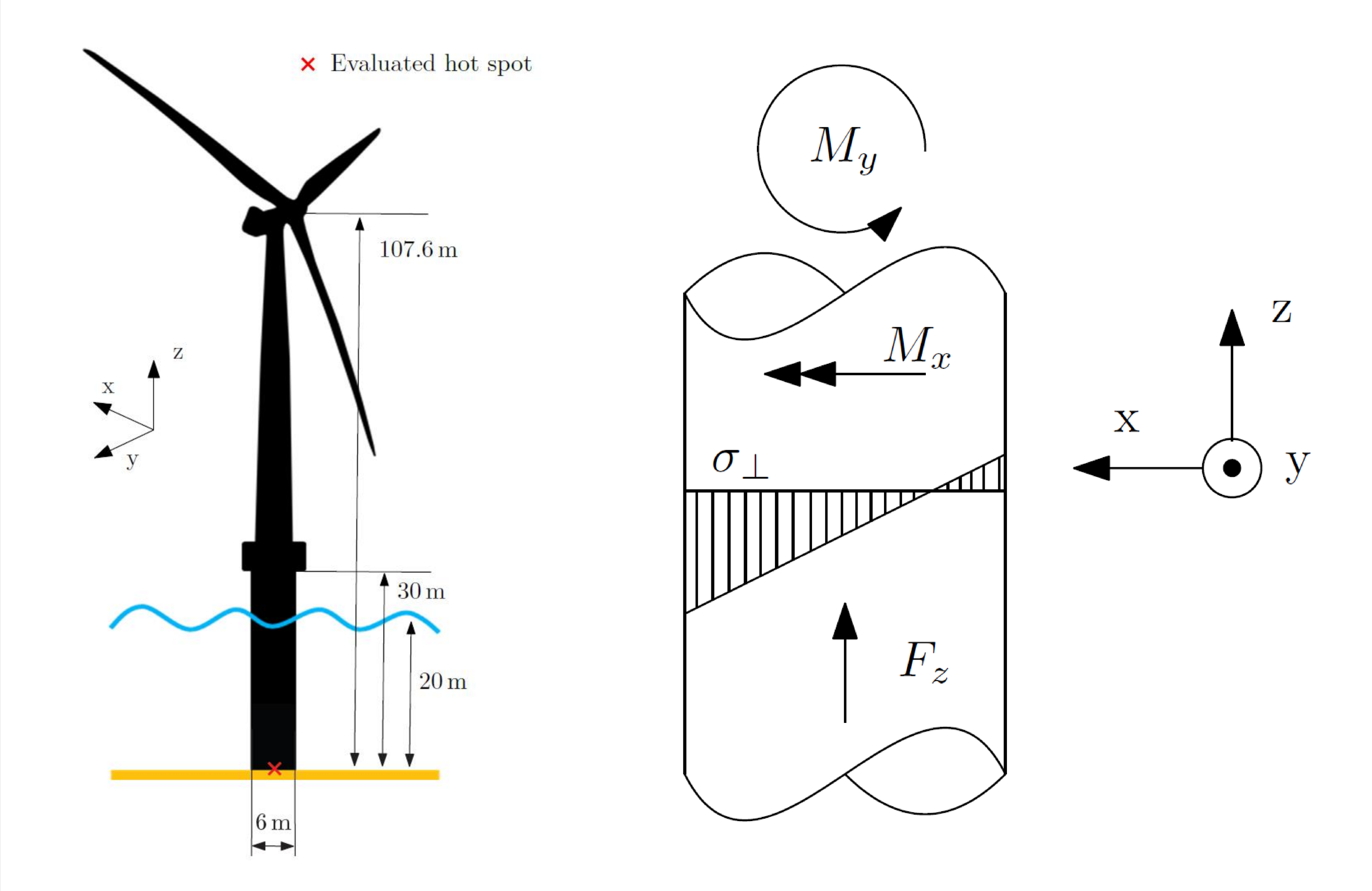
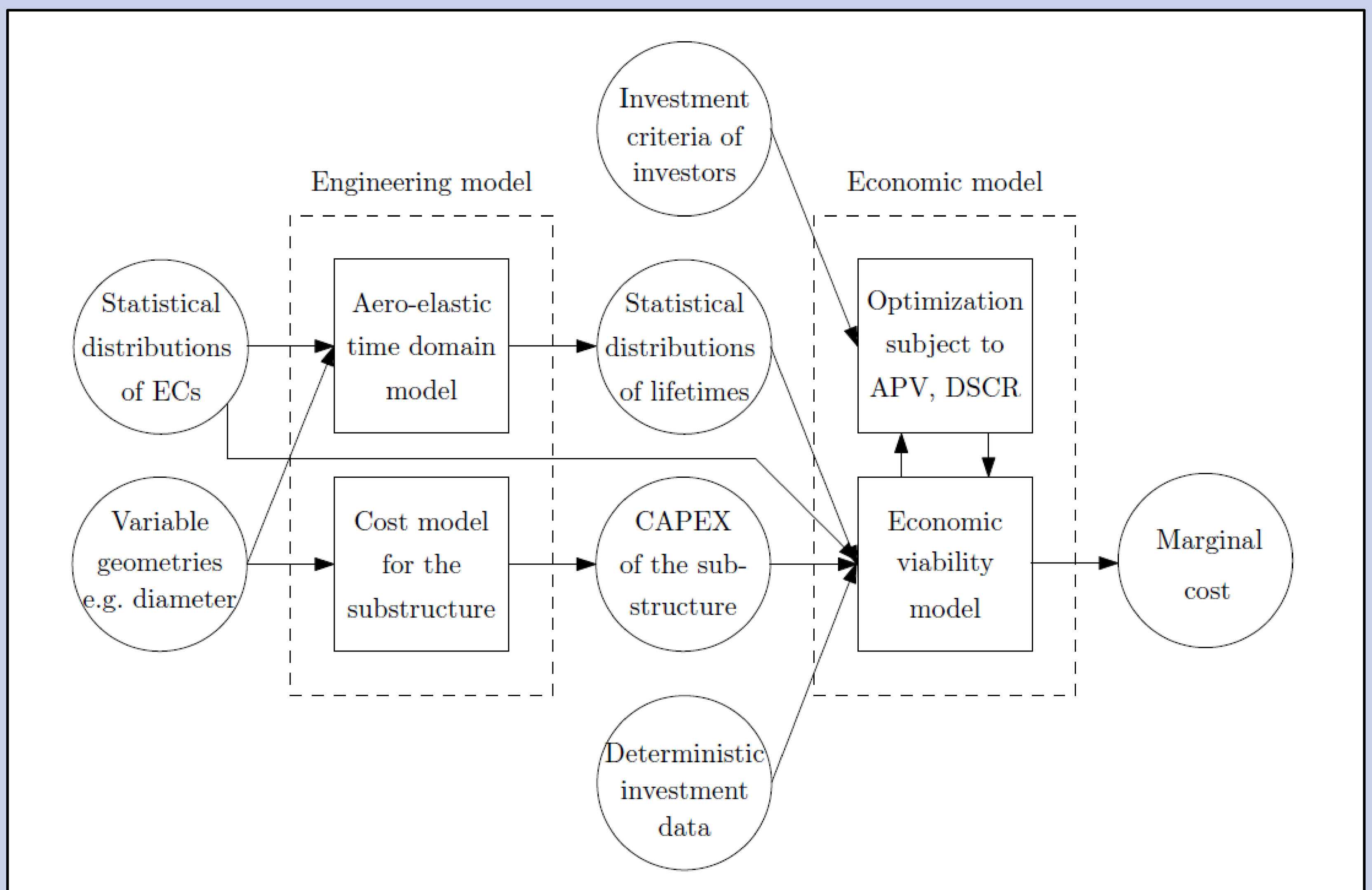


OC3 monopile and the NREL 5MW reference wind turbine and illustration of relevant forces and moments acting on the monopile cross section

Offshore wind turbine substructures and foundations account for nearly 20% of the total investment expenditures. Consequently, the optimization of structural designs with regard to **costs** and **reliability** is a promising approach to increase **cost efficiency** and **competitiveness** of offshore wind farms.

However, this requires a **change in paradigm** for optimal designs. In contrast to state-of-the-art optimization approaches, not only costs need to be minimized, but the **trade-off** between variable and **stochastic lifetime** and **component costs** needs to be analyzed in **interdisciplinary approaches** to find the most competitive structural design.

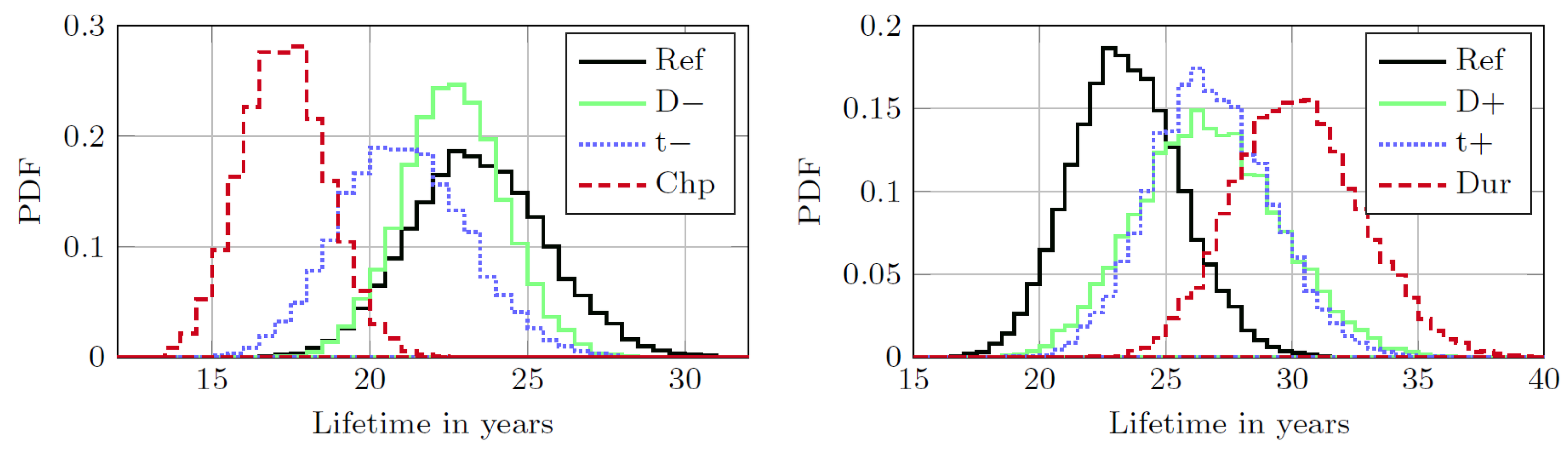


Interdisciplinary approach combining an engineering and an economic model

Simulation-Study and Results

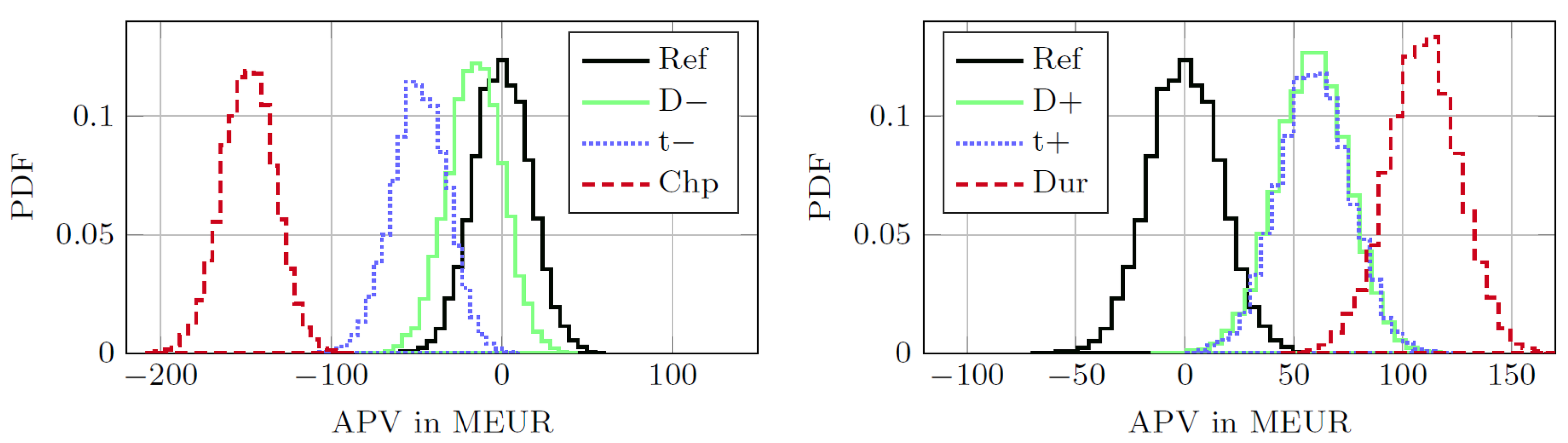
An **economic viability model** is combined with an **aero-elastic wind turbine model** and applied to an offshore wind farm in the North Sea under consideration of seven different **monopile designs**.

Design	Abbreviation	Change in diameter	Change in wall thickness	Substructure costs in MEUR	Difference
Reference	Ref	–	–	2.841	–
Design 2	D+	+1 %	–	2.872	+1.09 %
Design 3	D−	−1 %	–	2.810	−1.09 %
Design 4	t+	–	+2 %	2.879	+1.32 %
Design 5	t−	–	−2 %	2.804	−1.30 %
Design 6	Dur	+1 %	+2 %	2.911	+2.46 %
Design 7	Chp	−1 %	−2 %	2.775	−2.33 %



(a) Lifetime PDF for cheaper designs (b) Lifetime PDF for more durable designs

*Results of the **aero-elastic wind turbine model**: Costs and stochastic lifetimes of seven different substructure designs with different diameters and wall thicknesses.*



(a) APV PDF given the cheaper designs (b) APV PDF given the more durable designs

Design	Marginal cost (in ct/kWh) unltd	max30	max25	max20	Deviation from Ref unltd	max30	max25	max20
Ref	8.76	8.79	8.87	9.48	0.00 %	0.34 %	1.26 %	8.22 %
D+	8.35	8.42	8.69	9.48	−4.68 %	−3.88 %	−0.80 %	8.22 %
D−	8.88	8.88	8.88	**9.46**	1.37 %	1.37 %	1.37 %	**7.99 %**
t+	8.34	8.40	8.67	9.49	−4.79 %	−4.11 %	−1.03 %	8.33 %
t−	9.15	9.15	9.20	9.53	4.45 %	4.45 %	5.02 %	8.79 %
Dur	**8.02**	**8.17**	**8.65**	9.50	**−8.45 %**	**−6.74 %**	**−1.26 %**	8.45 %
Chp	9.99	9.99	9.99	10.05	14.04 %	14.04 %	14.04 %	14.73 %

*Results of the **economic viability model**: Marginal cost and stochastic project values of the analyzed offshore wind farm given each substructure design.*

Results indicate that the gain of increased stochastic lifetimes exceeds the benefits of reduced initial component costs on the substructures' competitiveness, if the project lifetime is not governed by other turbine components' lifetimes. Hence, **durable designs outperform cheaper designs** in most scenarios.

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