HAW HAMBURG | CC4E

University of Strathclyde Glasgow

RENEWABLE DYNAMICS

LCoE Calculator for MRS:

From Scaling Theory to Cost Evaluation

Anton Czemper, HAW Hamburg, 15.10.2025

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WIND CATCHING

Introduction and Research Objectives

Background

- Master thesis conducted over the last 6 months in collaboration with CC4E and SGRE

Research Objectives

- Develop and apply a cost & yield model (LCoE), based on existing HAW-CC4E-tool
- Compare multirotor vs. equivalent single-rotor concepts

Research Questions

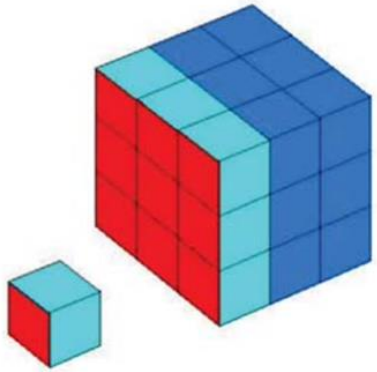
1. Suitability of scaling laws for modeling weight & costs
2. Selection of cost and yield parameters for reliable modeling
3. LCoE differences between multirotor and single-rotor concepts

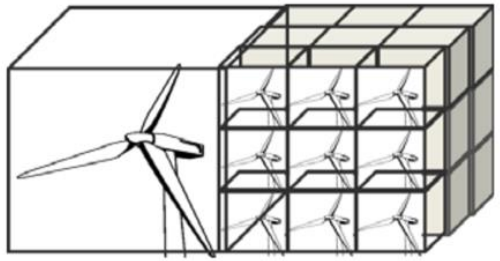
Scaling Theory Best Practice

1. Empirical Scaling Law (f.e. used in INNWIND Cost Model)

   ➢ Gearbox_mass=70,94*low_speed shaft torque^0,759

2. **Square Cube Law Approach** ✅

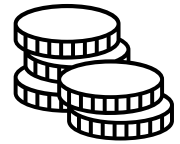




- $\frac{m}{m_{ref}} = \left(\frac{D}{D_{ref}}\right)^3$
- Up- and Downscaling Exponents
  - Upscaling: 2,6 ↑
  - Downscaling: 3 ↓
- Reference Turbine
  - Theoretical 3 MW Offshore Single Rotor from Erich Hau

Image: U. Goeltenbott, „Aerodynamics of Multi-Rotor Wind Turbine Systems using Diffuser-Augmentation“,

LCoE Calculation & Challenges in Cost Calculation



LCoE Formula

$$LCOE = \frac{I_0 + \sum_{t=1}^{n} \frac{A_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{M_{t,el}}{(1+i)^t}}$$

I_0	CapEx: Capital Expenditures
A_t	OpEx: Operational Expenditures
$M_{t,el}$	AEP: Annual Energy Production
i	WACC: Weighted average cost of capital
n	Economic lifetime in years
t	Year of operation (1,2, …n)

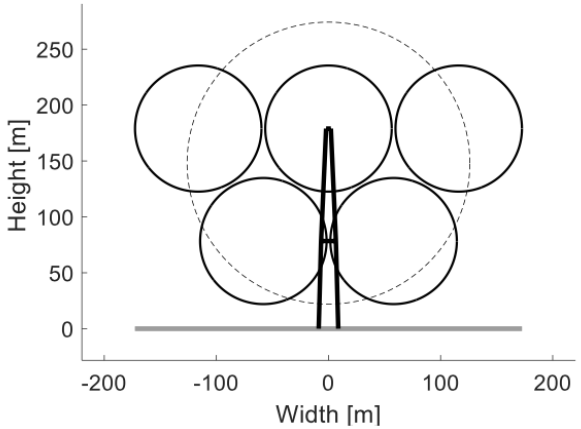
Challenges

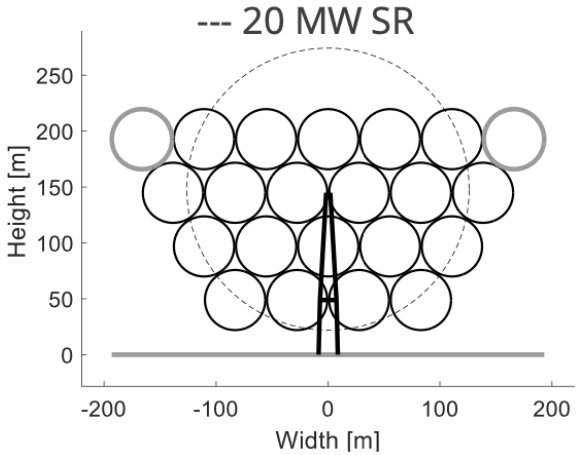
Price Data: Lack of up-to-date cost figures for turbine components → solved by price indexation of older sources

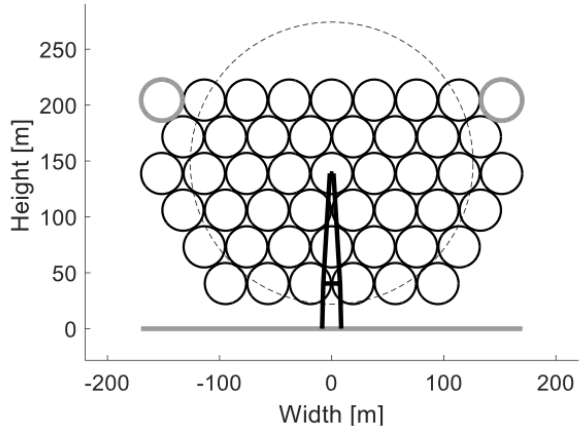
Economies of Scale: Determining correct technology factors for components; difference between multirotors (early-stage, higher potential, large number) vs. single rotors (mature, limited EoS)

CapEx Boundaries: Deciding which costs to include in Balance of Plant (BoP); e.g. decommissioning costs excluded (following Fraunhofer ISE approach)

Definition of Base Case

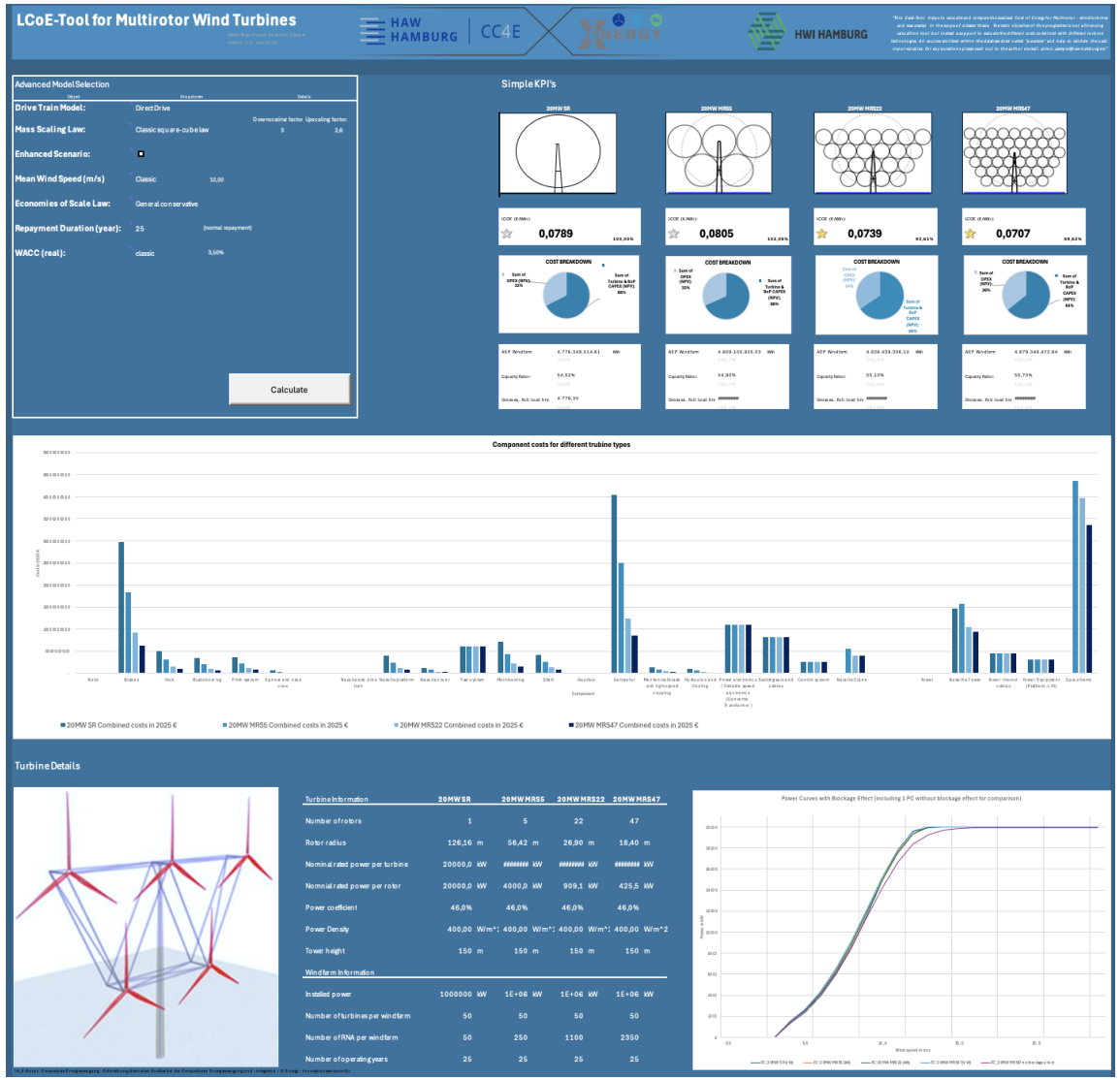


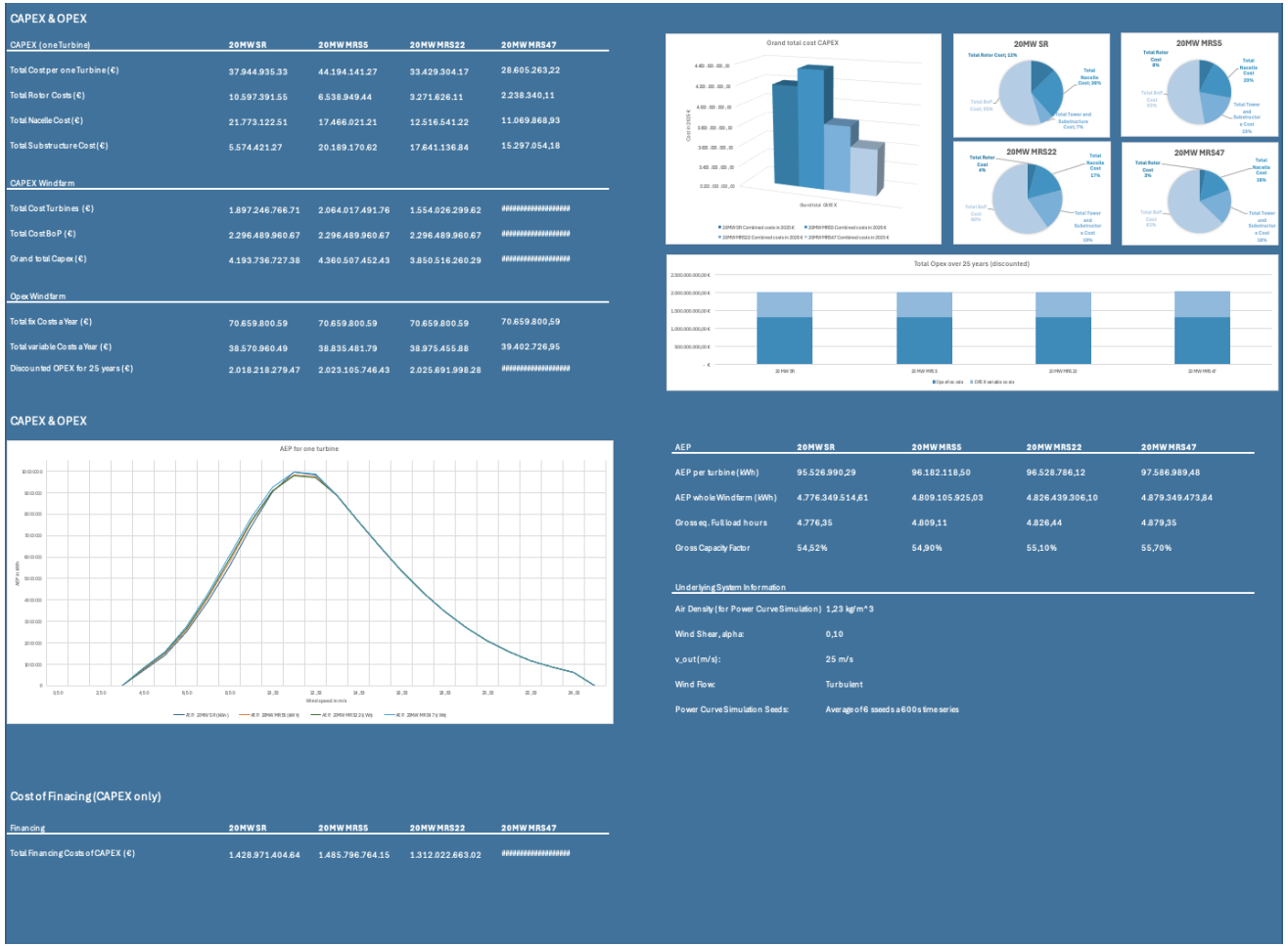




	20 MW SR	20 MW MRS5	20 MW MRS22	20 MW MRS47
Wind Farm Capacity	1 GW	1 GW	1 GW	1 GW
Number of Rotors	1	5	22	47
Power per Rotor	20.000 kW	4.000 kW	909,09 kW	425,53 kW
Rated Power of the Turbine (system)	20.000 kW	20.000 kW	20.000 kW	20.000 kW
Power Denisty	400 W/m^2	400 W/m^2	400 W/m^2	400 W/m^2
Rotor Radius	126,16 m	56,42 m	26,90 m	18,40 m
Operating Lifetime	25 years	25 years	25 years	25 years
Mean wind speed (turbulent)	10 m/s	10 m/s	10 m/s	10 m/s

Sven Störtenbecker, Peter Dalhoff, Rudolf Anselm, I4_X-Rotor: X-Energy - Teilprojekt: X-Multirotor und X-Rotor - Zweiblatt





LCoE-Calculator Dashboard

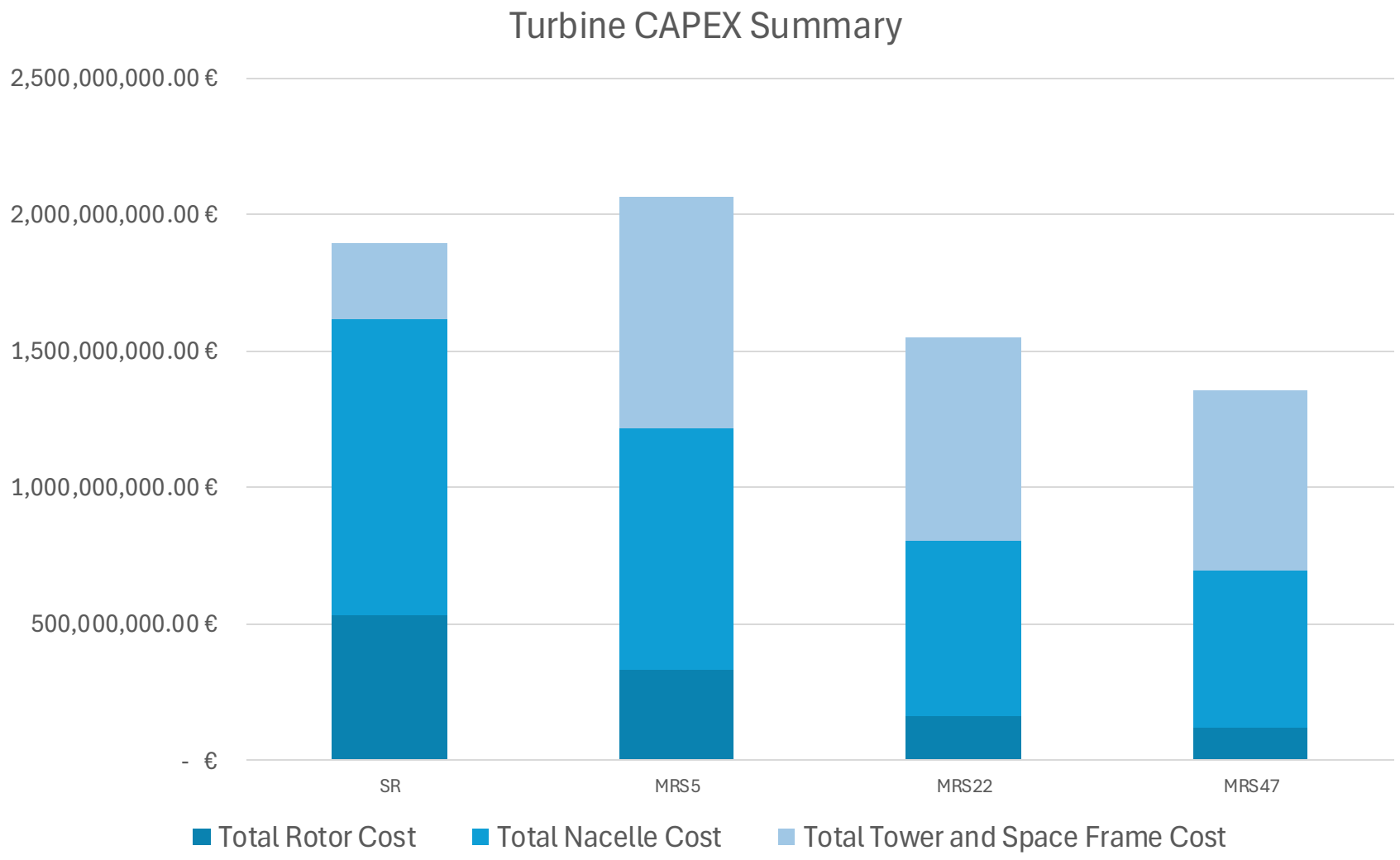
Key Results

		Single-Rotor	Multi-Rotor		
	Unit	20MW SR	20MW MRS5	20MW MRS22	20MW MRS47
LCoE	€/kWh	**0,0789**	**0,0805**	**0,0739**	**0,0707**
	%	100%	102,06%	93,61%	89,62%
Discounted ∑AEP	Mrd. kWh	**78,721**	**79,261**	**79,547**	**80,419**
	%	100%	100,69%	101,05%	102,16%
CapEx Total	Mrd. €	**4,193**	**4,360**	**3,850**	**3,653**
	%	100%	103,98%	91,82%	87,12%
CapEx Turbines (incl. Tower & Space-Frame)	Mrd. €	**1,897**	**2,064**	**1,554**	**1,357**
	%	100%	108,8%	81,9%	71,5%
CapEx BoP	Mrd. €	**2,296**	**2,296**	**2,296**	**2,296**
	%	100%	100%	100%	100%
Discounted ∑OpEx	Mrd. €	**2,018**	**2,023**	**2,025**	**2,033**
	%	100%	100,24%	100,37%	100,76%

Findings

Cost Reduction in CapEx

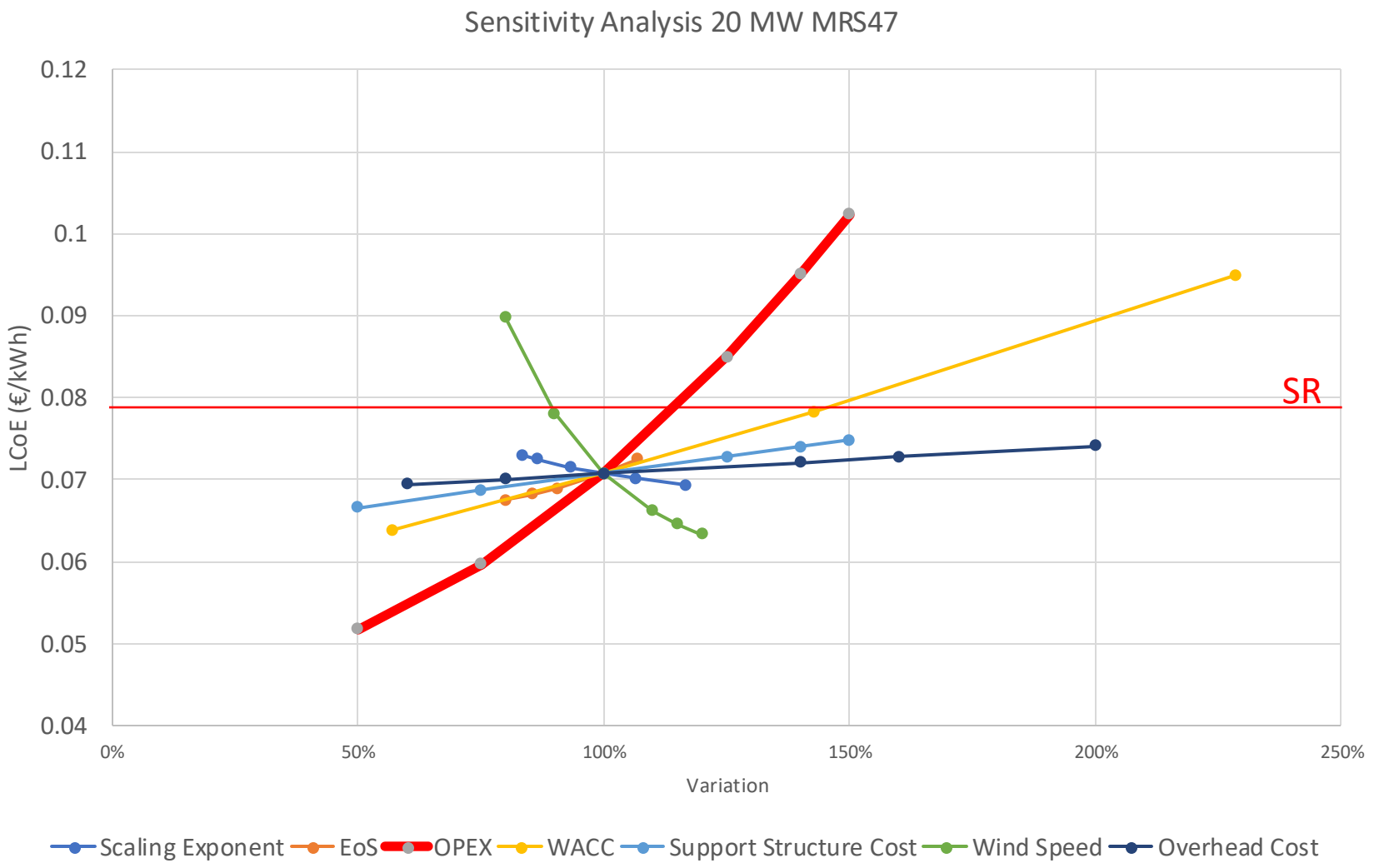
- Major driver of LCoE reduction is lower turbine CapEx
- Cost composition shifts between components (Rotor, Nacelle, Tower/Space Frame)
- RNA costs decrease with higher rotor number



Findings

Minor Cost Increase in OpEx

- Variable & Fix-Cost Approach from Fraunhofer ISE for Single Rotor does not fit MRS
- „X-Multirotor DfM“ will provided more realistic data that can be easily included in the LCoE Calculator



Conclusion

- Multirotor concepts show **potential for LCoE reduction** compared to single-rotor designs
- Main driver: **turbine CapEx** reduction, especially through RNA cost decrease
- Different cost composition: less rotor-driven, more tower & space frame
- Methodology provides a transparent calculation tool for future research & industry use

Thank you.

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