New approach on the comparability of two- and three-bladed 20 MW offshore wind turbines

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Who are we?

Cooperation project:

"X-Rotor – two-bladed wind turbines"

20 MW turbines of the next generation

HAW HAMBURG | CC4E

- University of Applied Sciences Hamburg
  - Competence Center for Renewable Energy and Energy Efficiency
    - ➢ 70 associates working in 30 renewable energy projects

SIEMENS Gamesa RENEWABLE ENERGY

- One of the biggest companies for wind turbines

Why two-bladed turbines?

Onshore:

Pro	Contra
• Cheaper rotor and drivetrain	• More noise
	• More unpleasant looks
	• **Lower power coefficient (Cp)**
	• More harmful dynamics

Why two-bladed turbines?

Offshore:

Pro	Contra
• Cheaper rotor and drivetrain	• More noise
• Faster and easier erection ➢ Small weather windows	• More unpleasant looks
• Less components ➢ Less maintenance	• **Lower power coefficient (Cp)** ➢ **Extend rotor size by 2%**
• Better access by helicopter ➢ Faster maintenance	• More harmful dynamics ➢ Today better controllable (active or passive)
• Lower turbine head mass ➢ Less inertia if floating	

Why are there only few two-bladed turbines?

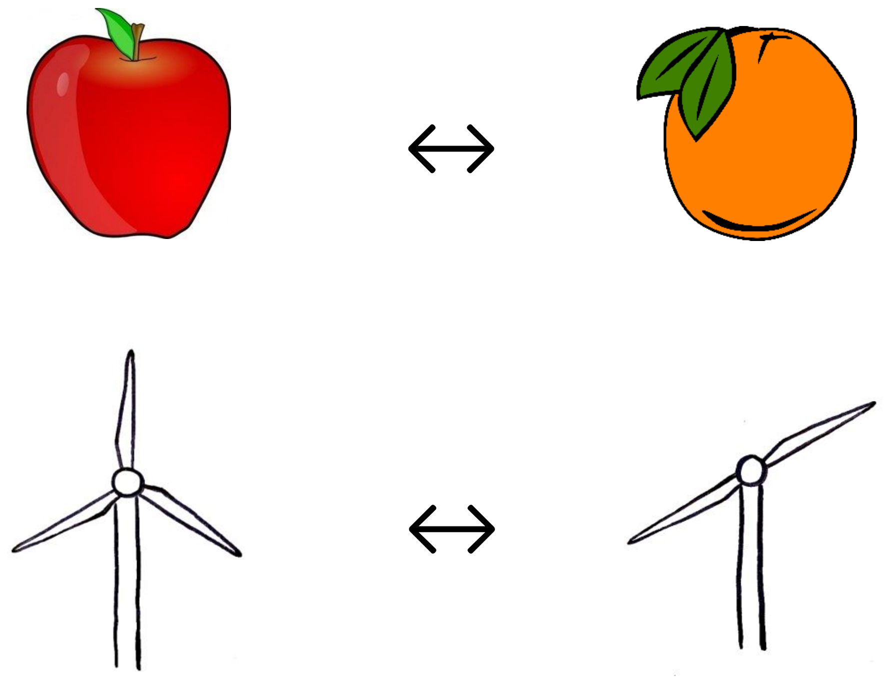
➢ Investors demand proven technology and long-time track record of turbines

➢ Benefits not yet completely quantified

Comparability and the lower Cp-value

“Clear-cut comparisons between two- and three-bladed machines are notoriously difficult because of the impossibility of establishing equivalent designs.”

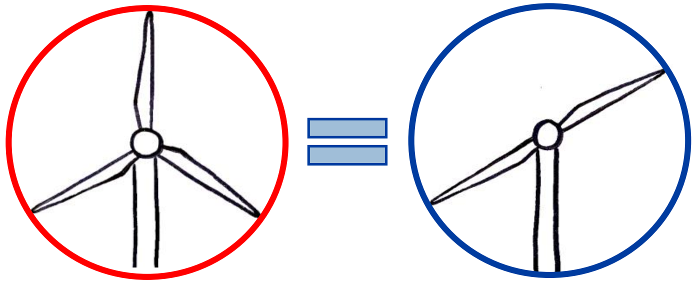
- Tony Burton, Wind Energy Handbook



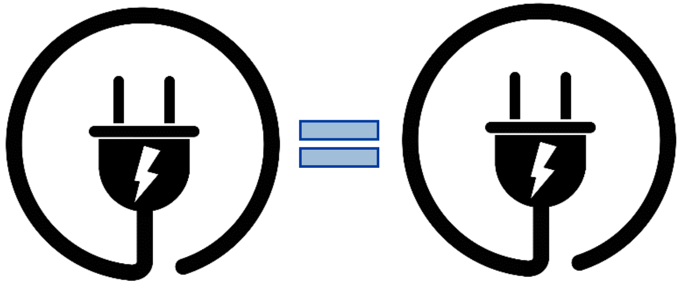
Comparability and the lower Cp-value

Usual constrain: Rotor diameter remains unchanged

- ➢ Result: Higher tip losses, thus lower Cp, thus lower power

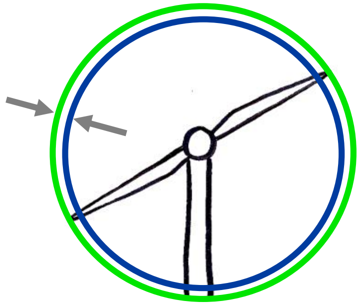


VS.

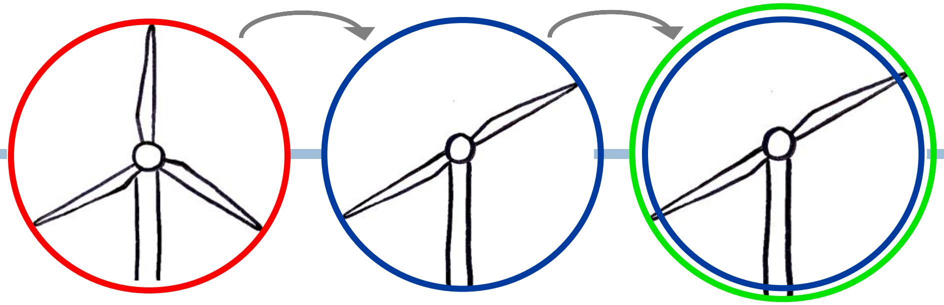


Our approach: Absolute power-curve remains unchanged

- ➢ Result: Rotor diameter is around 2% higher
  Mass increases by around 8%



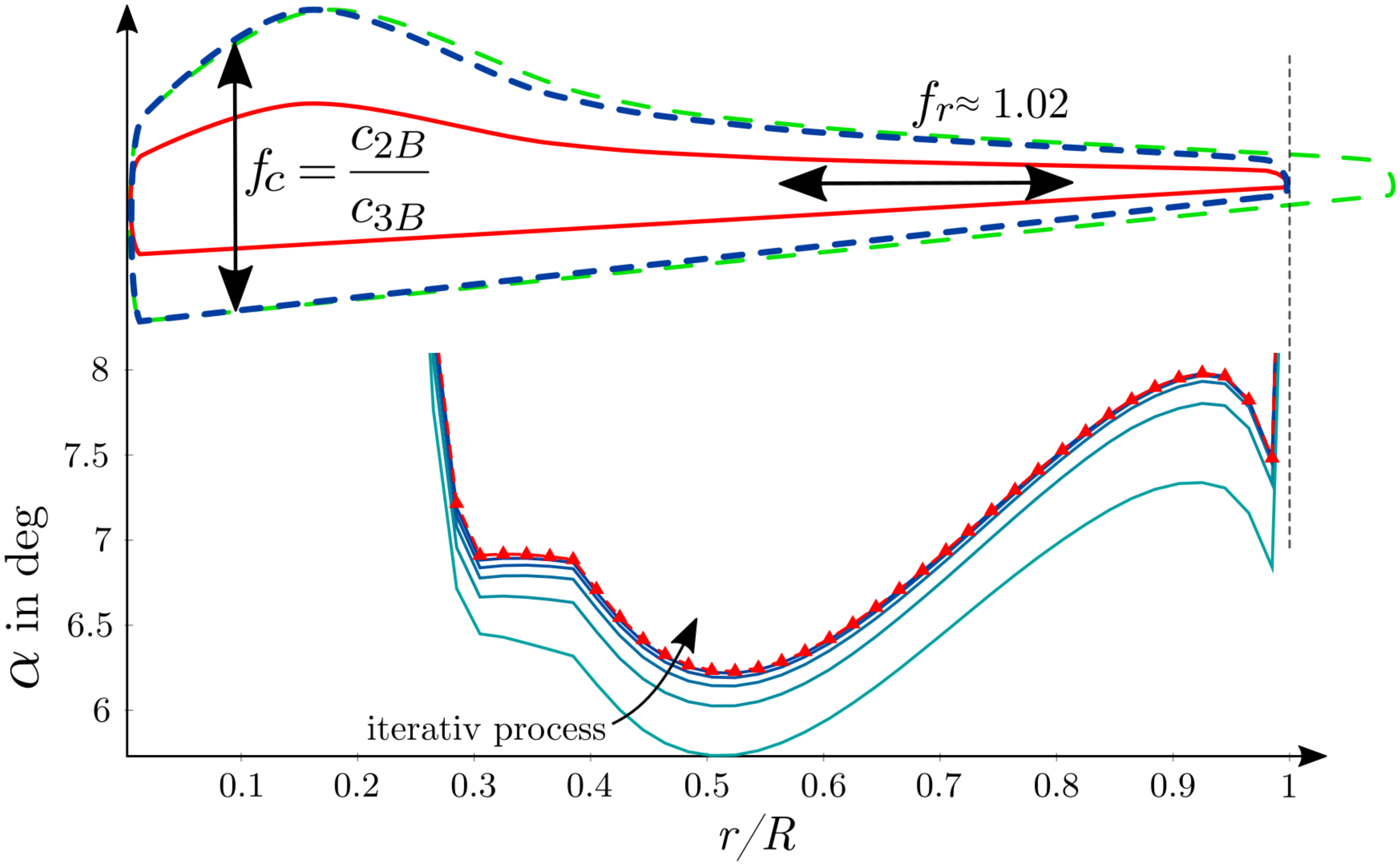
Comparability and the lower Cp-value



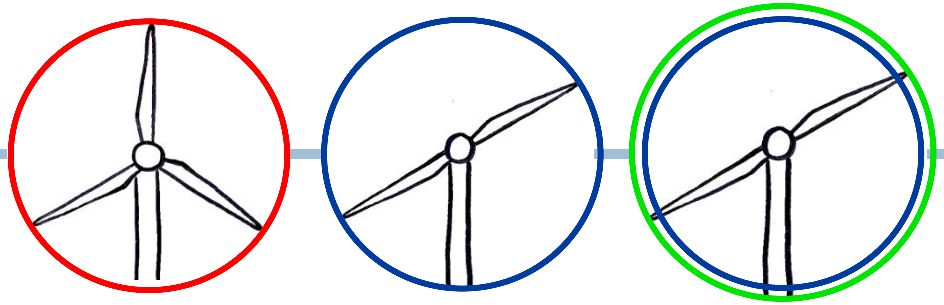
Our approach in detail:

- Similar aerodynamics due to same airfoils, same relative chord length c, same angle of attack α, thus same optimal glide angle
- Scale blade by

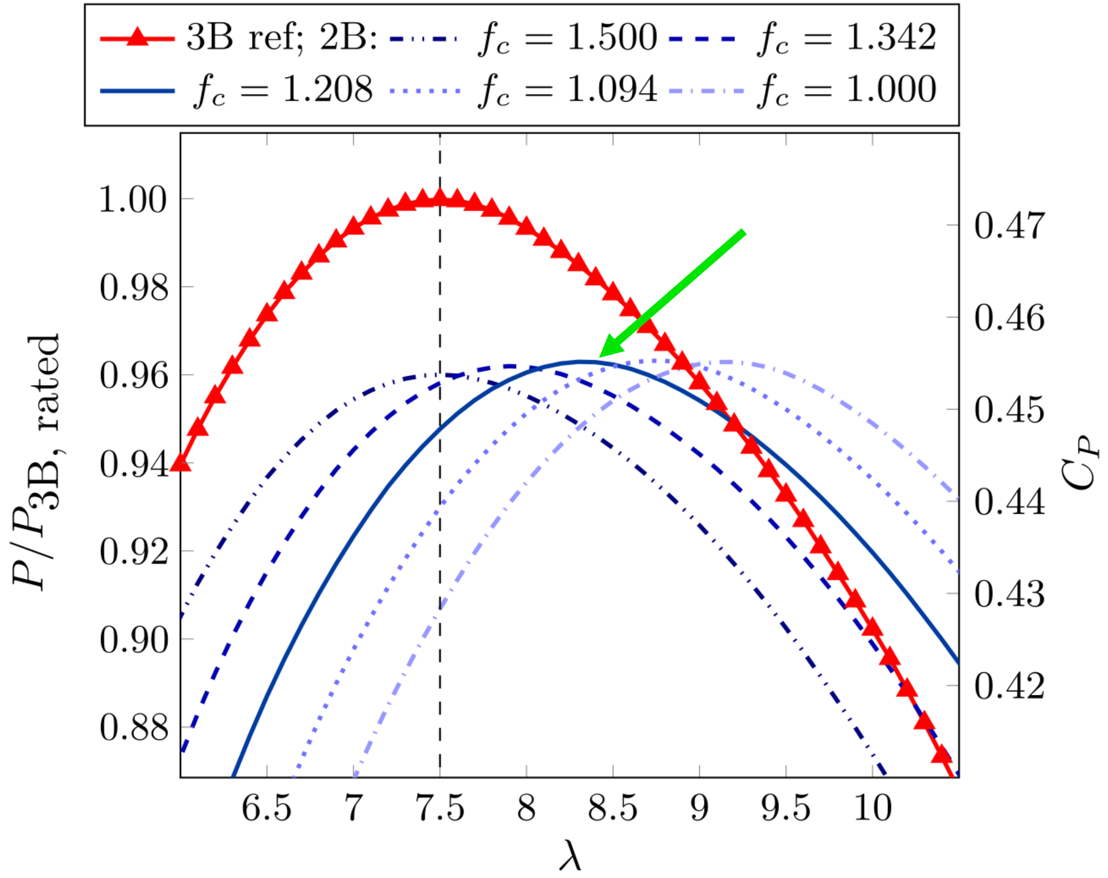
$$f_r = \frac{R'_{2B}}{R_{3B}} = \sqrt{\frac{P_{3B,rated}}{P_{2B,rated}}}$$



Chord variation (f_C) of the INNWIND 20 MW RWT

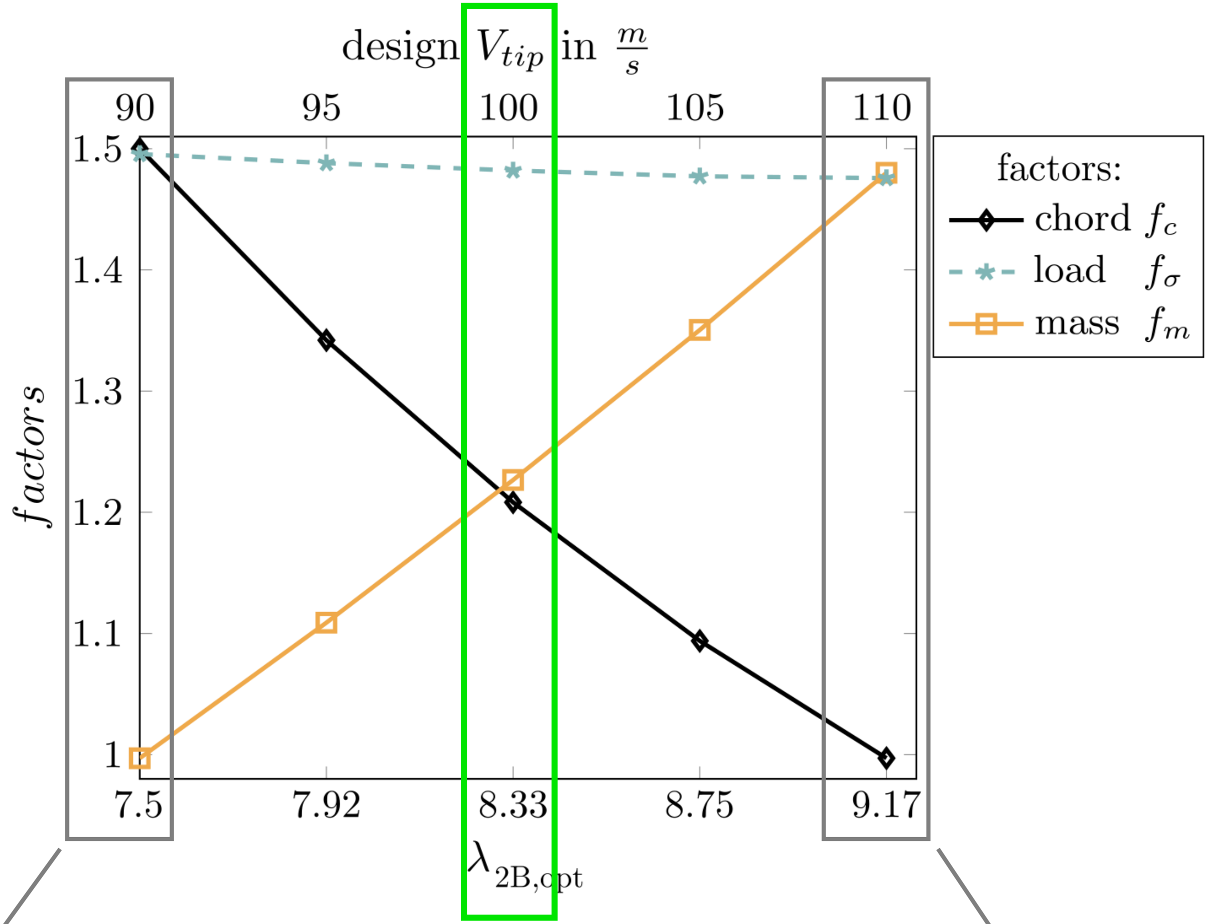


Comparison with equal diameter:



$$f_c = \frac{c_{2B}}{c_{3B}} \approx 1.5 \left(\frac{\lambda_{3B,opt}}{\lambda_{2B,opt}} \right)^2$$

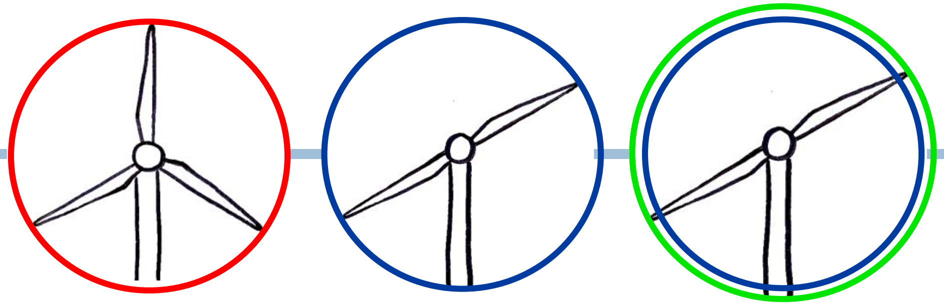
$$\lambda = \frac{\omega R}{V_{wind}}$$



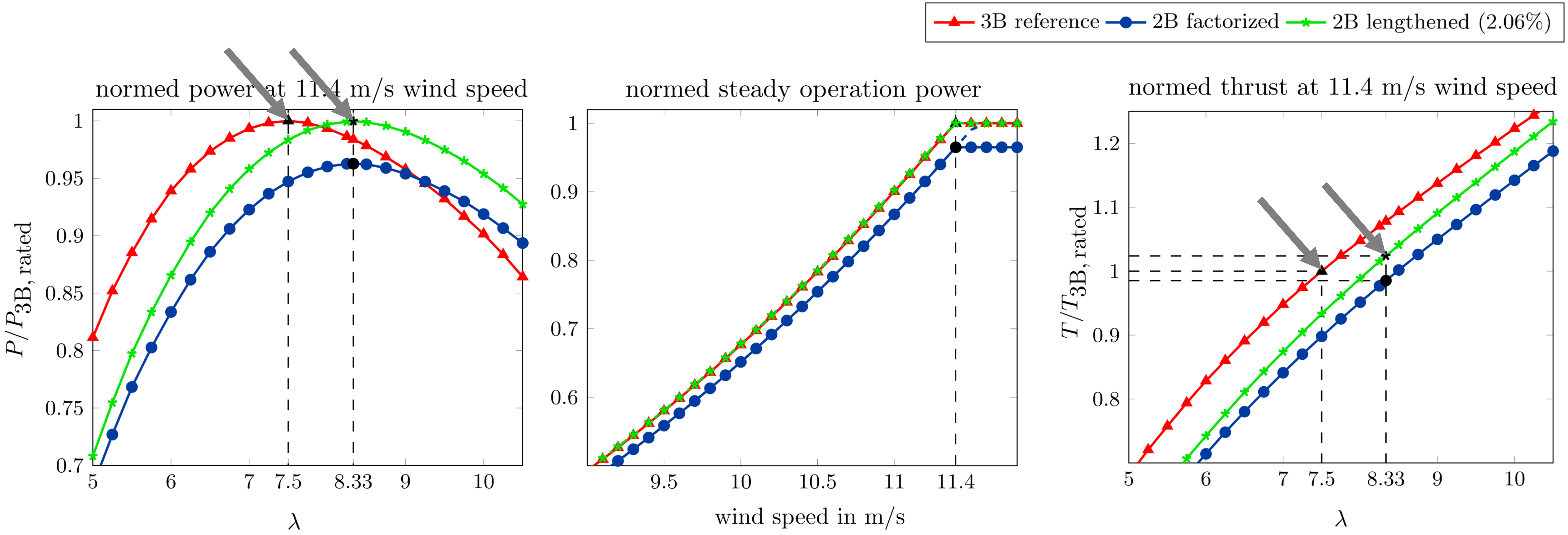
Structural benefits

cheaper drivetrain (less torque & higher speed)

Power vs. Thrust



Loads, e.g. thrust, can be compared directly:



Summary and Conclusions

Equal absolute power is only possible with increased rotor radius of ~2% (for Cp-max designs) → Design point at rated remains together with all its implications on the turbine

Before: 2- and 3-bladed turbines were compared by levelized cost of energy at the end of the design → Now: Compare loads (e.g. thrust), masses or costs, during the whole design process and derive clues about diverging values

Clear method to redesign a 2-bladed turbine out of a 3-bladed one → High reproducibility and similar aerodynamics, thus clear assessments of symptoms and causes

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Thank you for your attention!

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Source: Levin Schilling