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RENEWABLE DYNAMICS

Open-source reference rotor library for multi-rotor aeroelastic modelling and design

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UKRI Engineering and Physical Sciences Research Council

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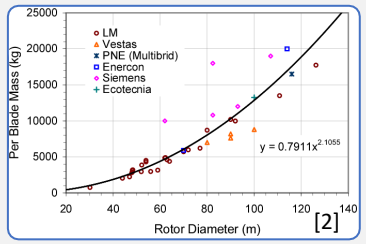
WIND CATCHING

Background – A fair comparison?



Not a perfect solution…

- Complexity
- Vibrations & Stability
- Support structure mass
- Rotor interaction (+/-)

- Issues with single rotors are evidenced and well understood
- Complicating factors for multi-rotors still have many unknowns

⇒ Non-equivalent comparison – easy to overpredict advantages

[1] Rr2000, via Wikimedia Commons. [2] Crawford, C. A., Proceedings of the Canadian Engineering Education Association (CEEA) (2011). [3] P. Adams Schwertentransporte. LinkedIn. [4] Benjamin Rasmussen/Getty Images. Bloomberg. [5] Dale Ricker. Times Herald. [6] Maarten Paul van der Laan et al., Wind Energy Science 4 (2 2019), pp. 251–271.

Path to Design Optimisation

Research gaps

- Reduced RNA mass
- Improved AEP
- Simplified O&M
- Built-in redundancy

- Cost of Energy
- Environmental Impact

Optimiser

- Aerodynamics
- Cost model
- Control
- Structural dynamics
- O&M Model
- Life cycle assessment

Aero-servo-elastic design optimisation using **ATOM V2***

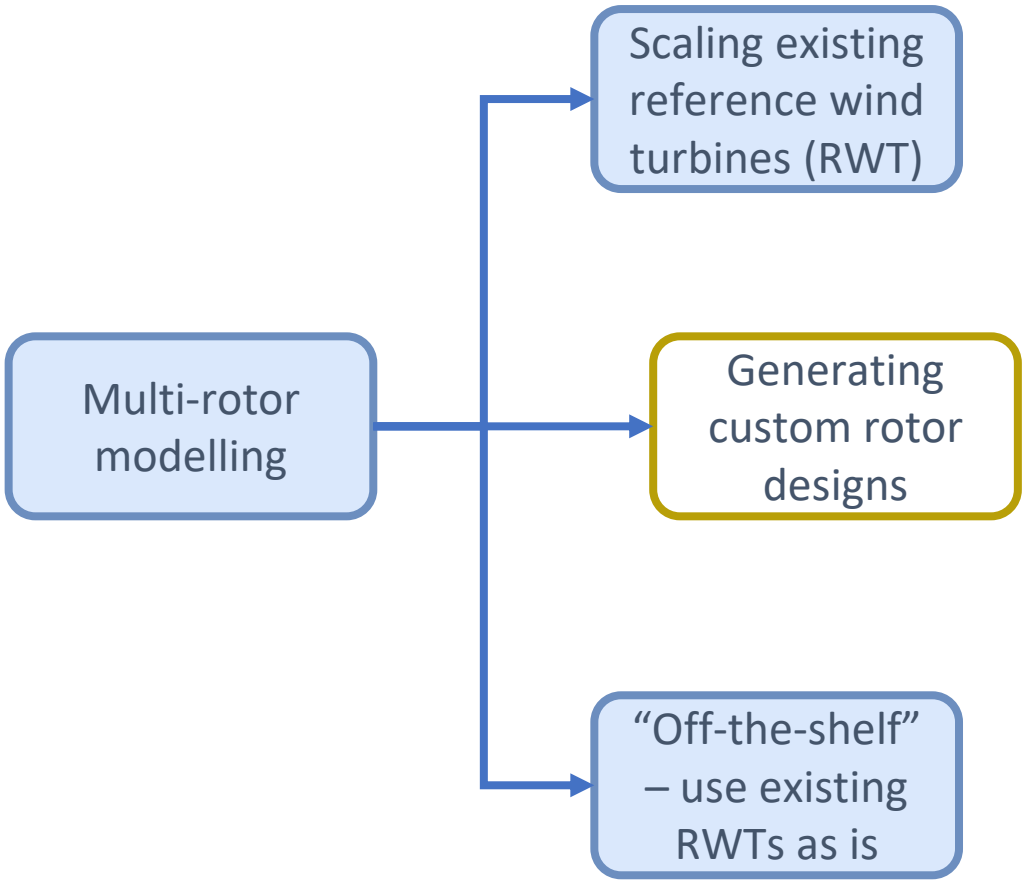
Comparing a mature design against **optimised** novel designs

*Aeroelastic Turbine Optimisation Methods (ATOM)
Scott, S. et al., Journal of Physics: Conference Series, 1222(1) (2019).

Small Rotor Design Project

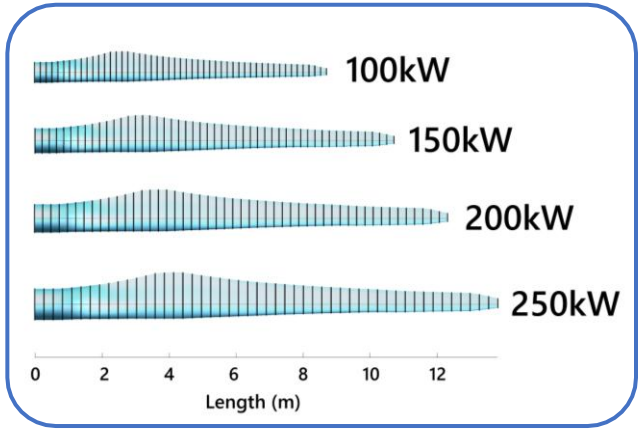
Reference rotors for multi-rotor modelling

Small Rotor Design Project



Designing optimised library of blades for multi-rotor modelling

Publishing models open-source



- Standardised initial design
- Optimisation of chord, twist, and thickness distributions
- Rotor interpolation

✓ Equipping the MRWT research community with the tools to rapidly explore a wide range of designs

Design Procedure

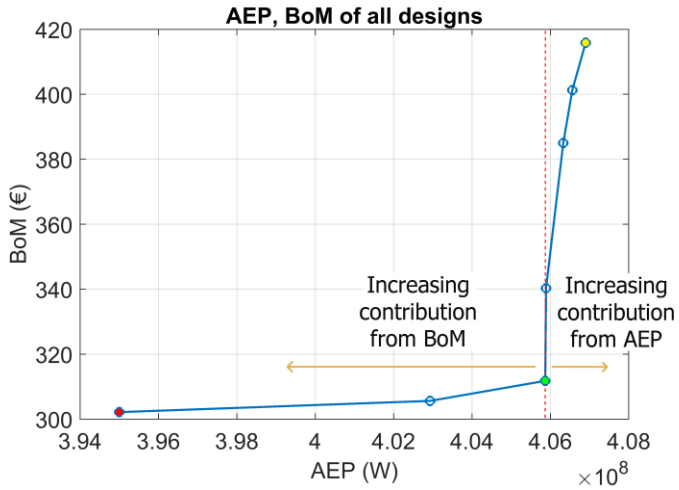
Initial sizing via empirical formulae

Aero-servo-elastic optimisation with Design Load Cases (DLCs)

Objective function

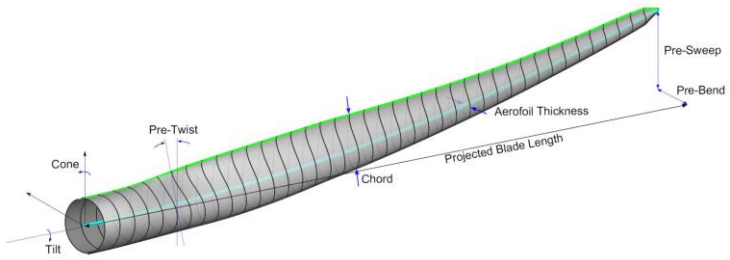
Existing cost models not applicable to small rotor scale

- Analogue objectives to LCoE explored



Design Variables

Aerodynamic DVs (chord, twist) + structural DVs (layup thicknesses)



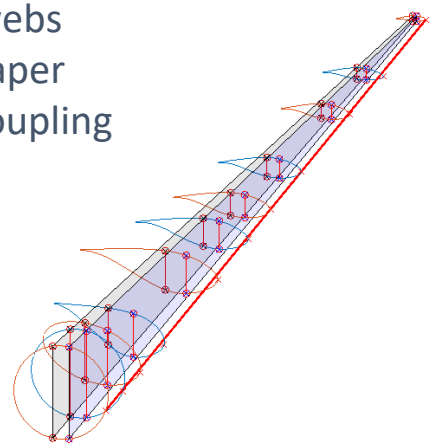
Constraints

Operational feasibility

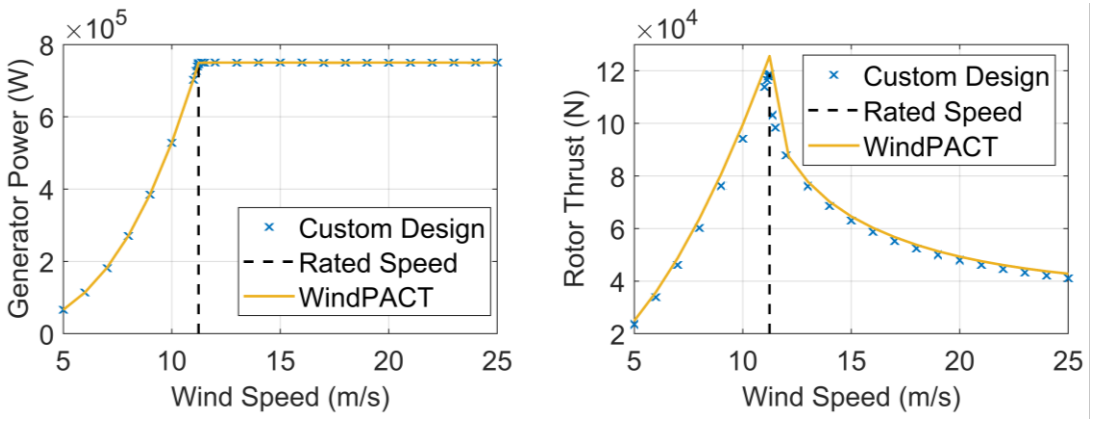
- Failure in strain, buckling or fatigue
- Aeroelastic stability

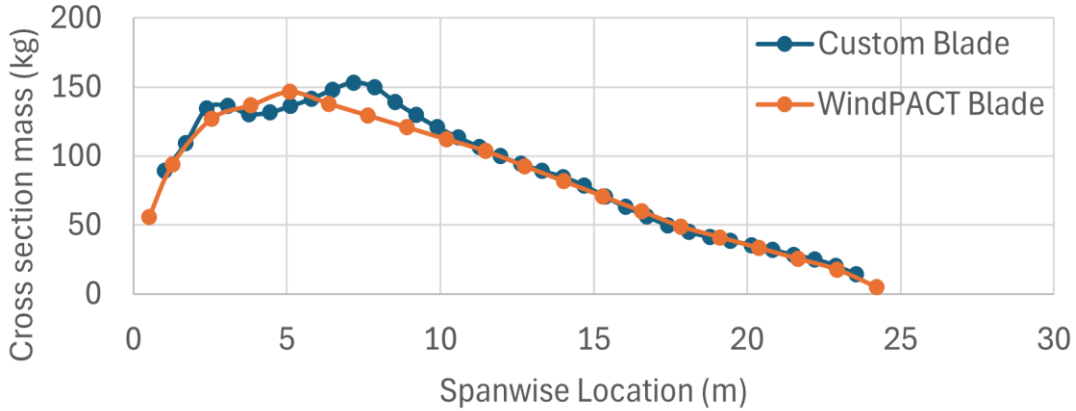
Simple/high-volume manufacture

- Straight webs
- Max ply taper
- Limited coupling



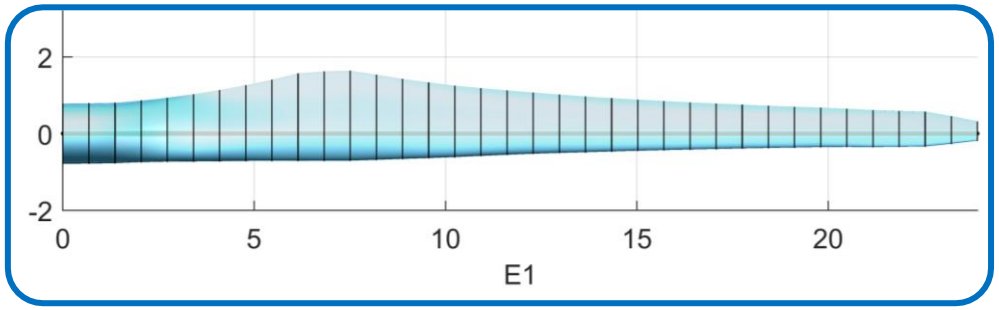
Representative Designs



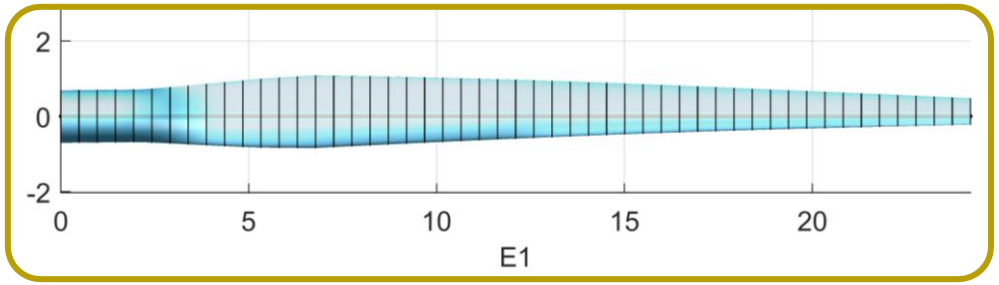


Sample designs:

- 100kW – baseline model
- 750kW – comparison against existing RWT



750KW design from custom library

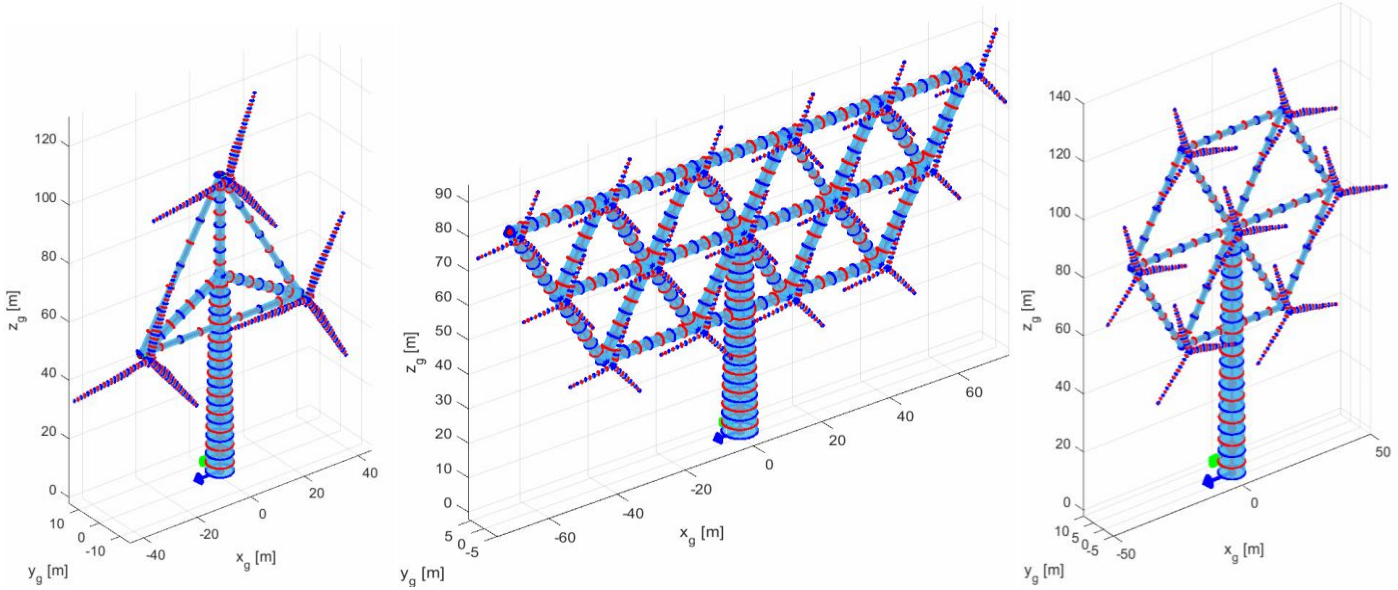


WindPACT 750kW RWT

Model Implementation

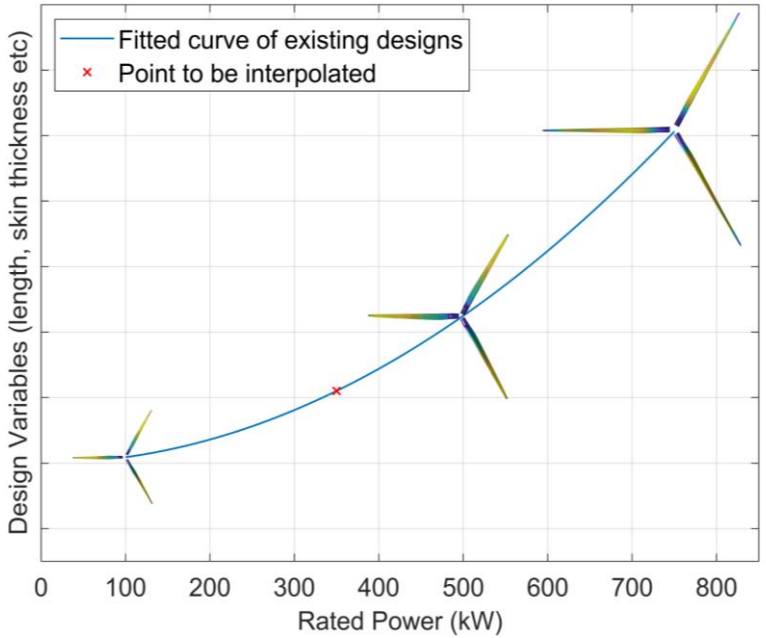
Example: find the best multi-rotor arrangement for 3MW

- Design library limits the available arrangements



3 x 1MW | 15 x 200kW | 7 x 428.6kW

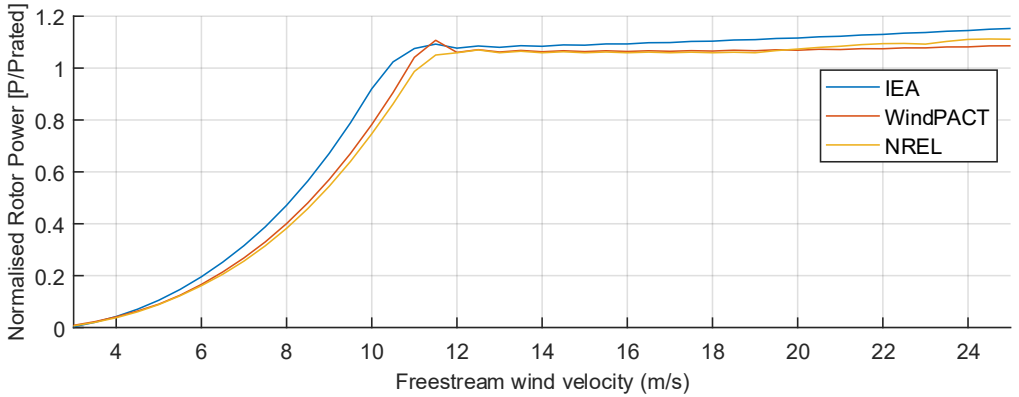
- Solution: generate intermediate designs by interpolating
  - Enabling custom model creation

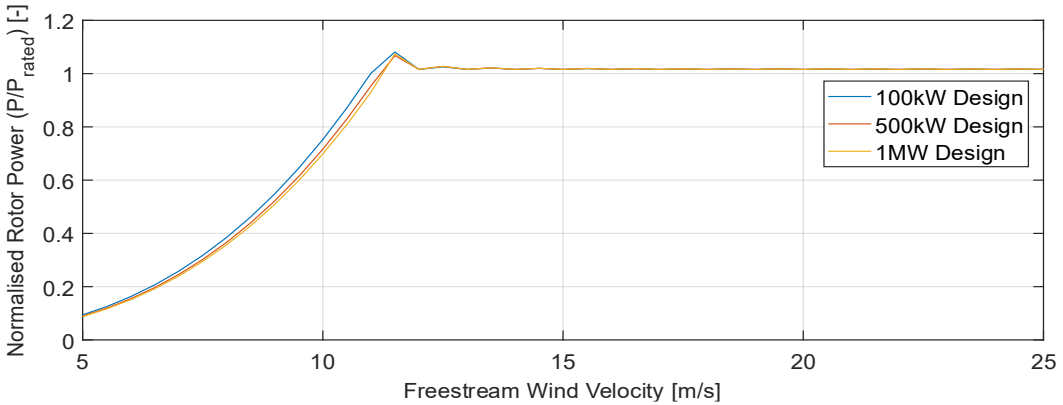


Design Validity

Validity of inter-rotor comparison?

Progress on improving equivalence?



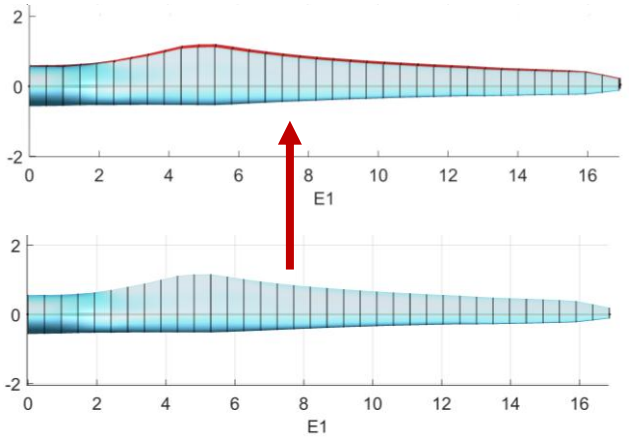


Validity of interpolation?

Compare interpolated and optimised designs

Optimised 375kW

Interpolated 375kW

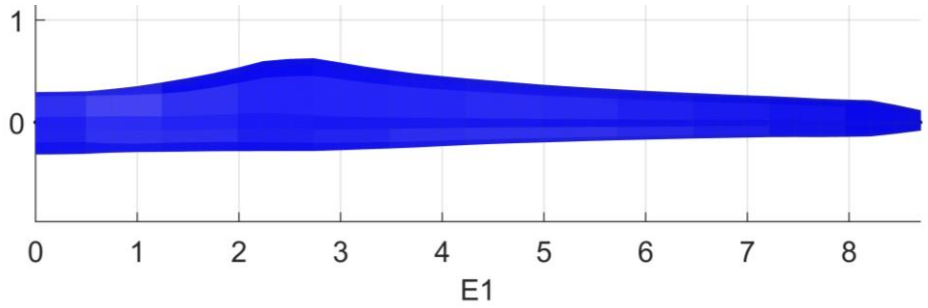


Model	Blade mass (kg)	AEP (GWh)	Thrust @ rated (kN)
Optimised	1046.7	1.3783	55.476
Interpolated	1153	1.3749	55.321

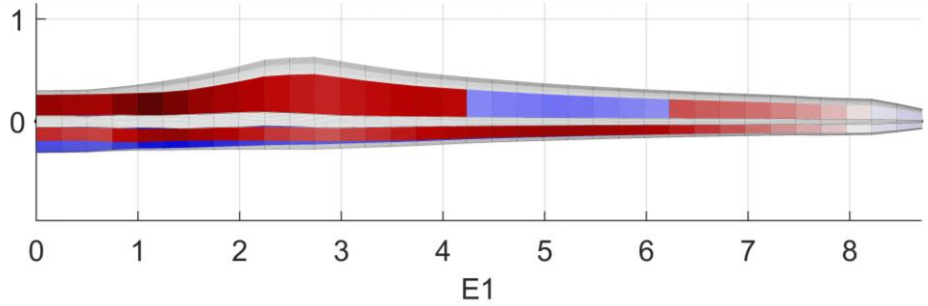
Natural Fibre Composites

MRWTs as an enabling technology for (more) sustainable blades?

- Smaller blades → reduced structural requirements
- Investigating partial deployment of natural fibre composite



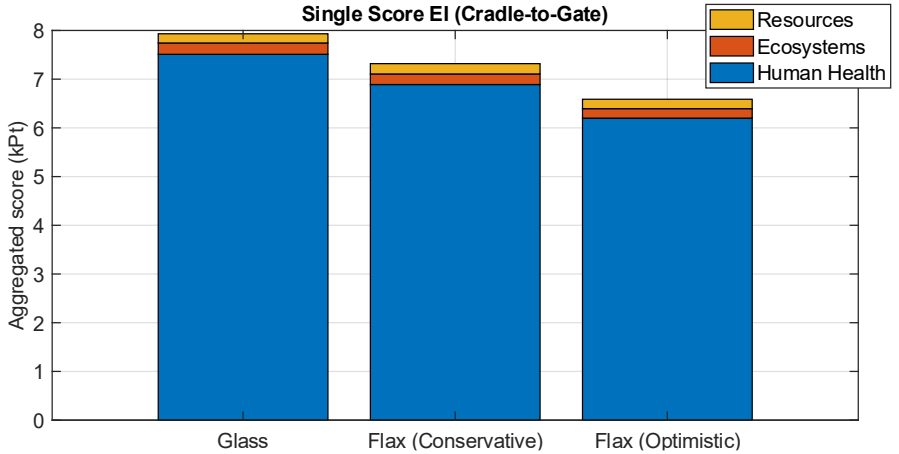
Baseline 100kW Design (GFRP)



Hybrid design (Flax biax/triax)

Motivation

- Lower structural properties → heavy blades
- Lower volume fraction → greater resin mass
  - Limits environmental impact reduction

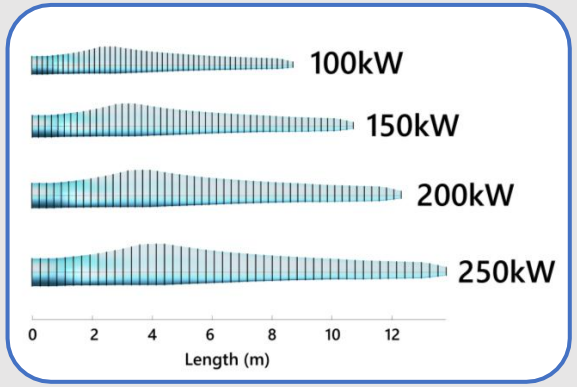


- Reduce rotor size
- Hybrid designs

→ Improve environmental performance!

Next Steps

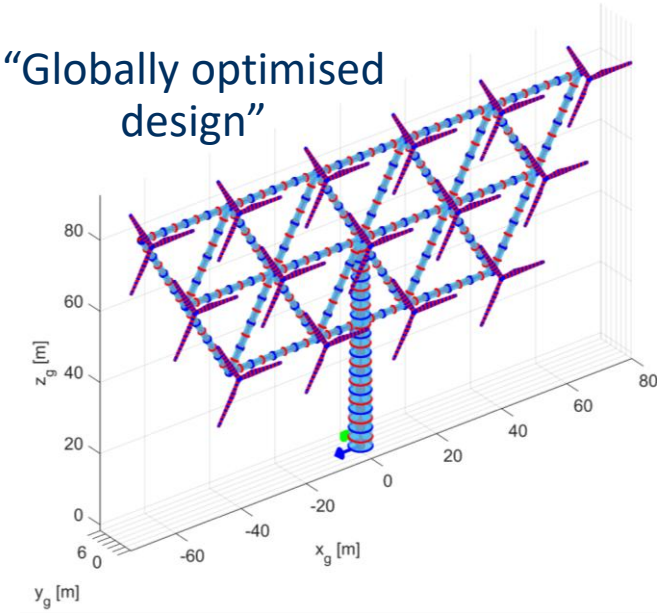
Individual blade optimisation



- Minimising LCoE
- Improving cost/simplicity of manufacture
- Improving life cycle environmental impact

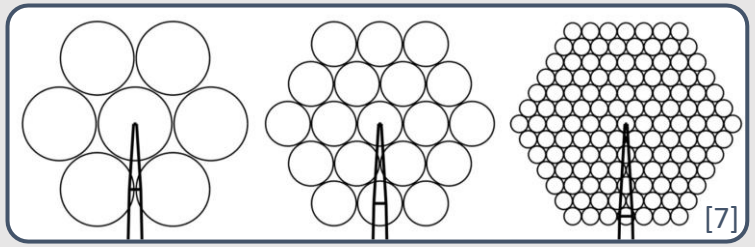
ATOM V2

"Globally optimised design"



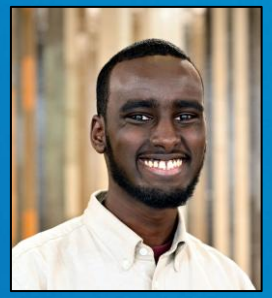
Comprehensive comparison against equivalent single-rotor

Support structure parametrisation



- Capturing coupled multi-body dynamics
- Generating custom rotors based on library
- Rapidly exploring large range of designs

[7] Störtenbecker, S. et al, Journal of Physics: Conference Series (2020)



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Thank you.

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