Potential of MgB2 superconductors on direct drive generators for wind turbines

Abrahamsen, Asger Bech; Liu, Dong; Magnusson, Niklas; Polinder, Henk

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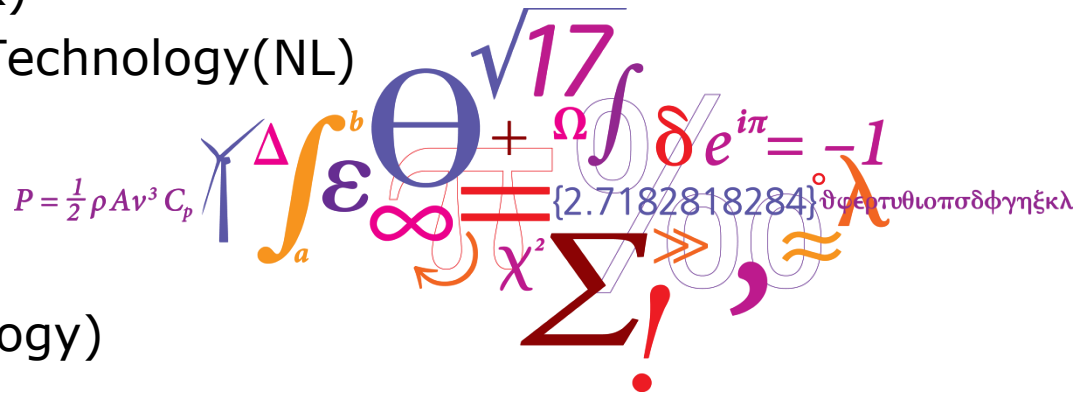
Potential of MgB_2 superconductors on direct drive generators for wind turbines

Asger B. Abrahamsen[1], Dong Liu[2], Niklas Magnusson[3] and Henk Polinder[2]

[1]DTU Wind Energy, Technical University of Denmark(DK)
[2]Electrical Power Processing Group, Delft University of Technology(NL)
[3]SINTEF Energy Research(N).



Innovation in wind turbine drive trains (Turbine technology)
Thursday 19 November 2015 14:30-16:00
EWEA 2015, Paris

DTU Wind Energy
Department of Wind Energy

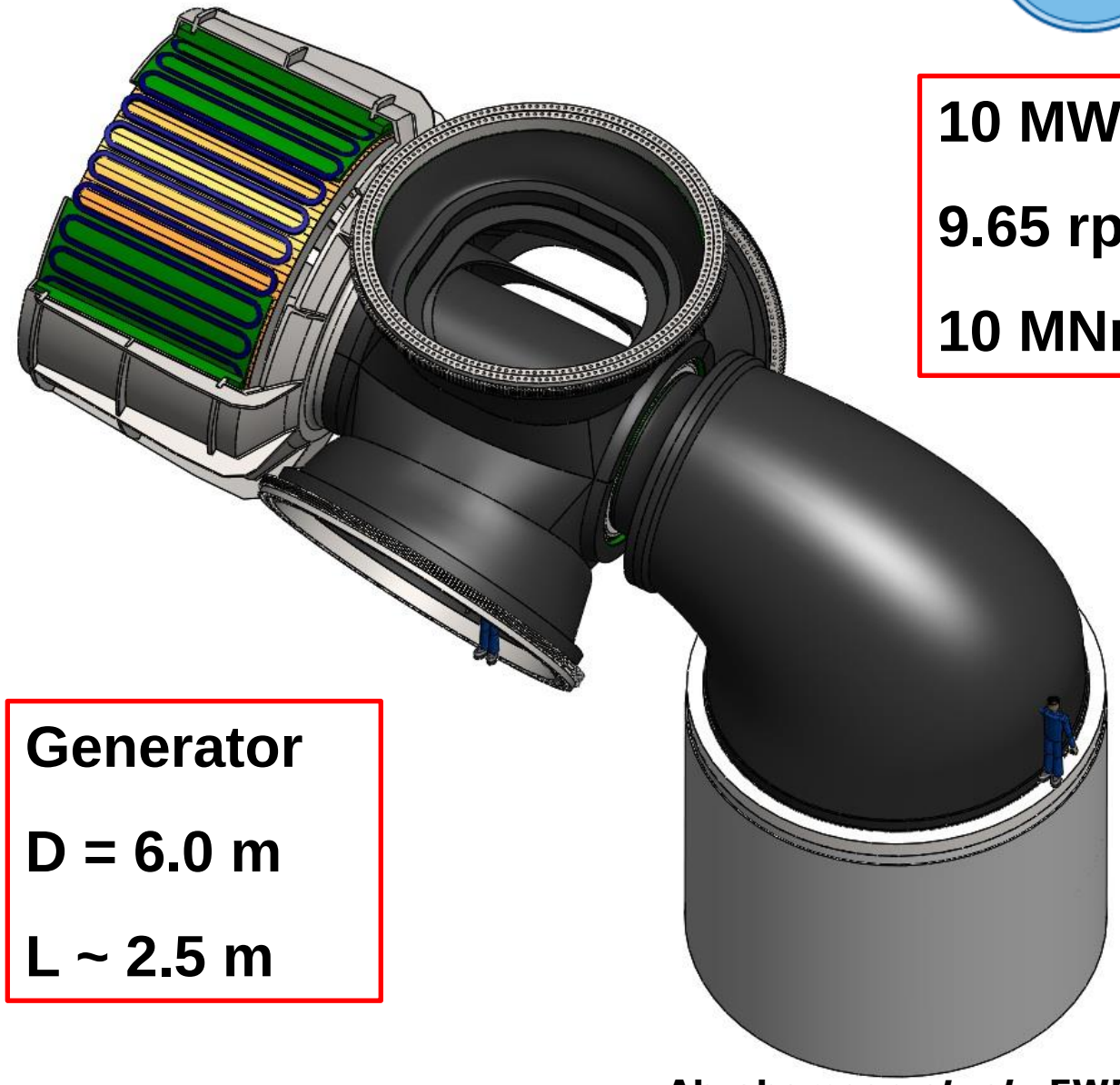
TU Delft

SINTEF

INNWIND.EU

Outline

- Motivation
- Design philosophy
- Generator optimization
- Active material cost
- Road map for 10 GW
- Conclusion



10 MW

9.65 rpm

10 MNm

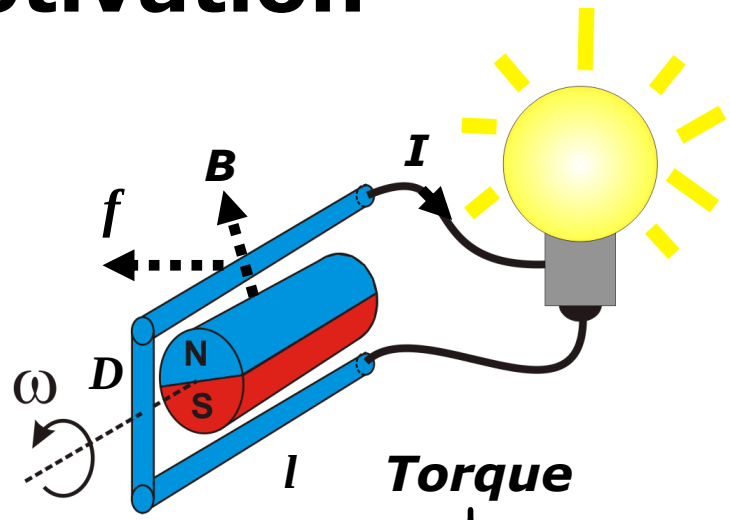
Generator

D = 6.0 m

L ~ 2.5 m

Abrahamsen *et. al.*, EWEA 2014

Motivation



Torque

$$Power \propto BI\ D^2 l\ \omega$$

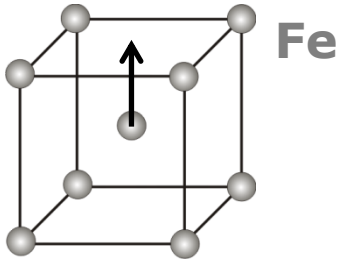
1G : Copper coils + Iron

2G : $R_2Fe_{14}B$ magnets + Fe

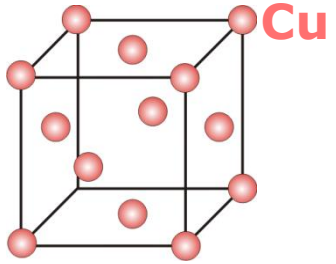
10 MW ~ 6 tons PM

3G : MgB_2 coils + Fe

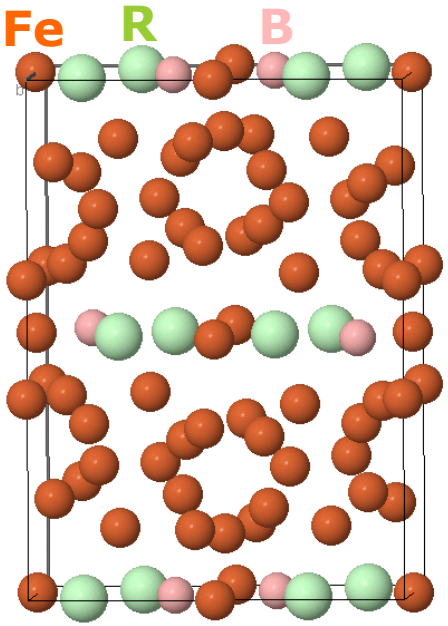
10 MW ~ No Rare Earth



T_C = 770 °C

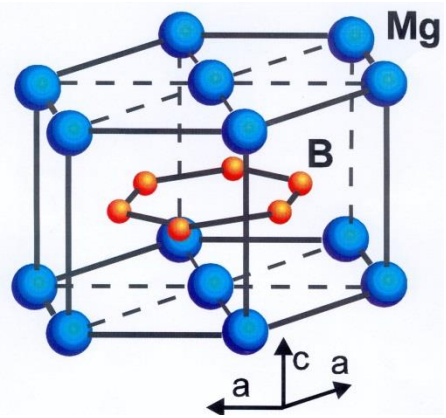


J ~ 2 A/mm²



T_C = 310 °C

B_r ~ 1.4 T



T_C = - 234 °C

B_{c2} ~ 40 Tesla

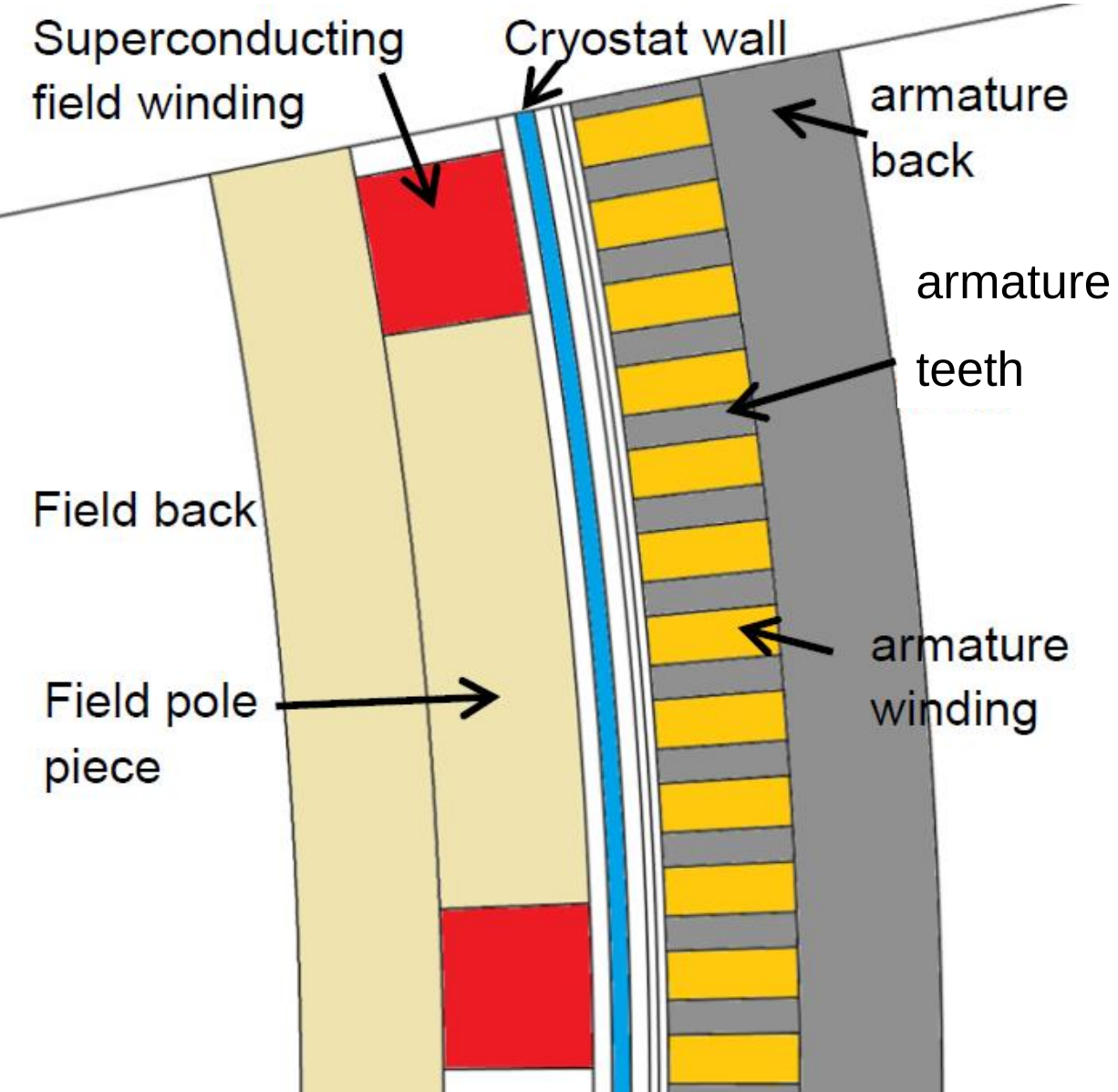
J < 10000 A/mm²

Columbus wire

0.7 mm

3.0 mm

Best topology for MgB_2 wires in WTG?

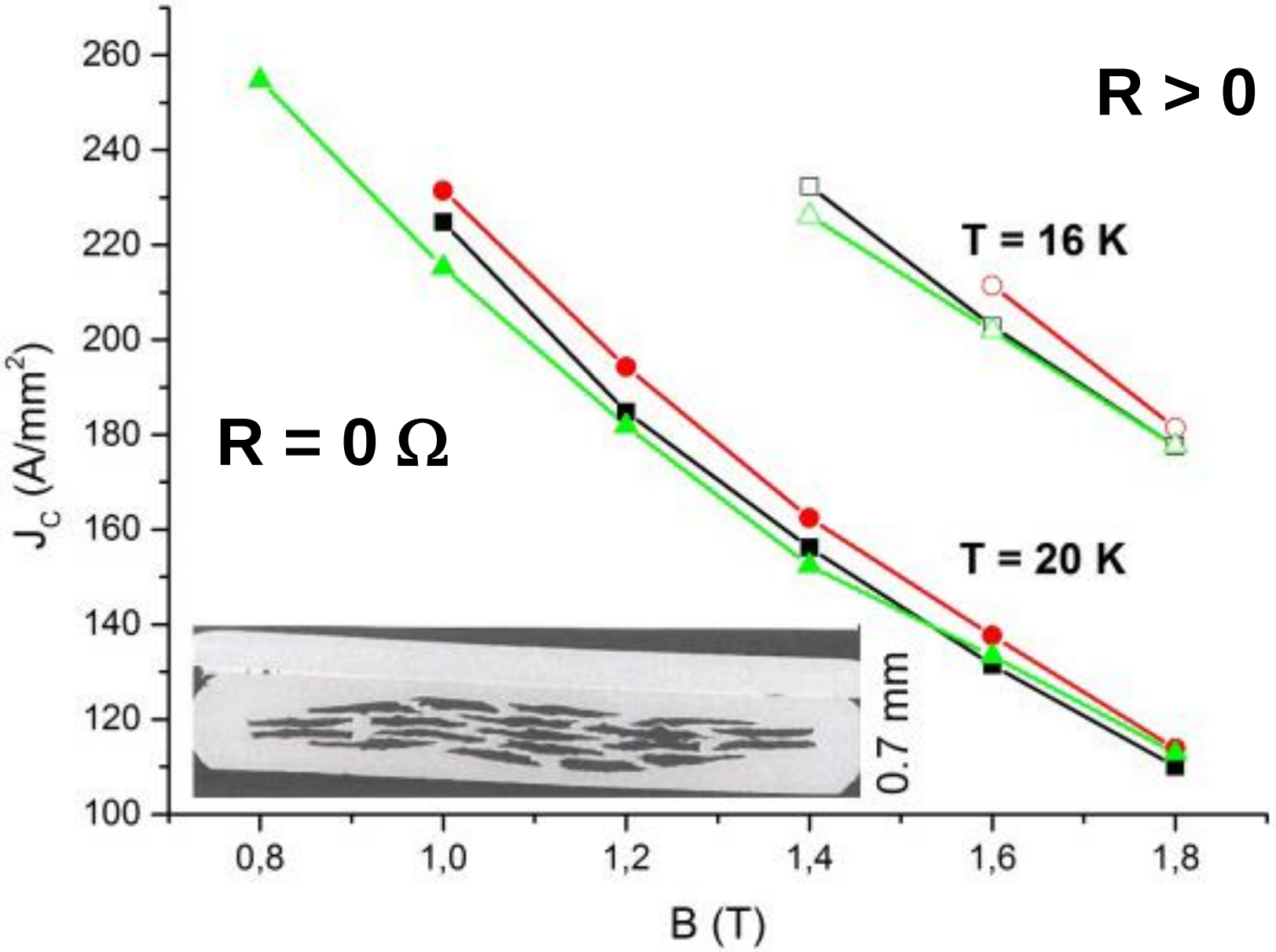


Design philosophy:

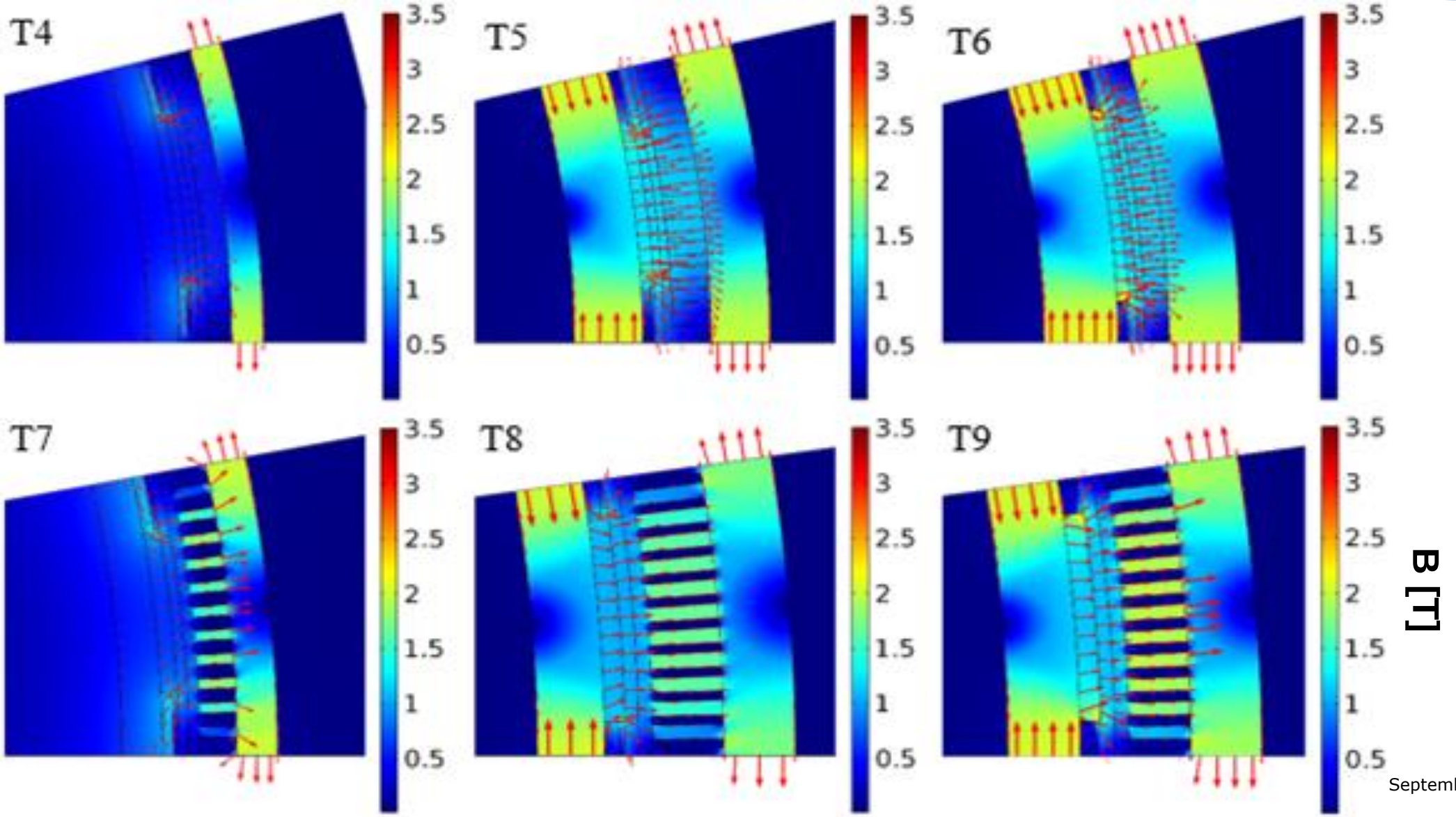
Put as much iron as possible to minimize magnetic flux path

MgB_2:	4 €/m
Fe:	3 €/kg
Cu:	15 €/kg
G10:	15 €/kg
PM:	50-75 €/kg

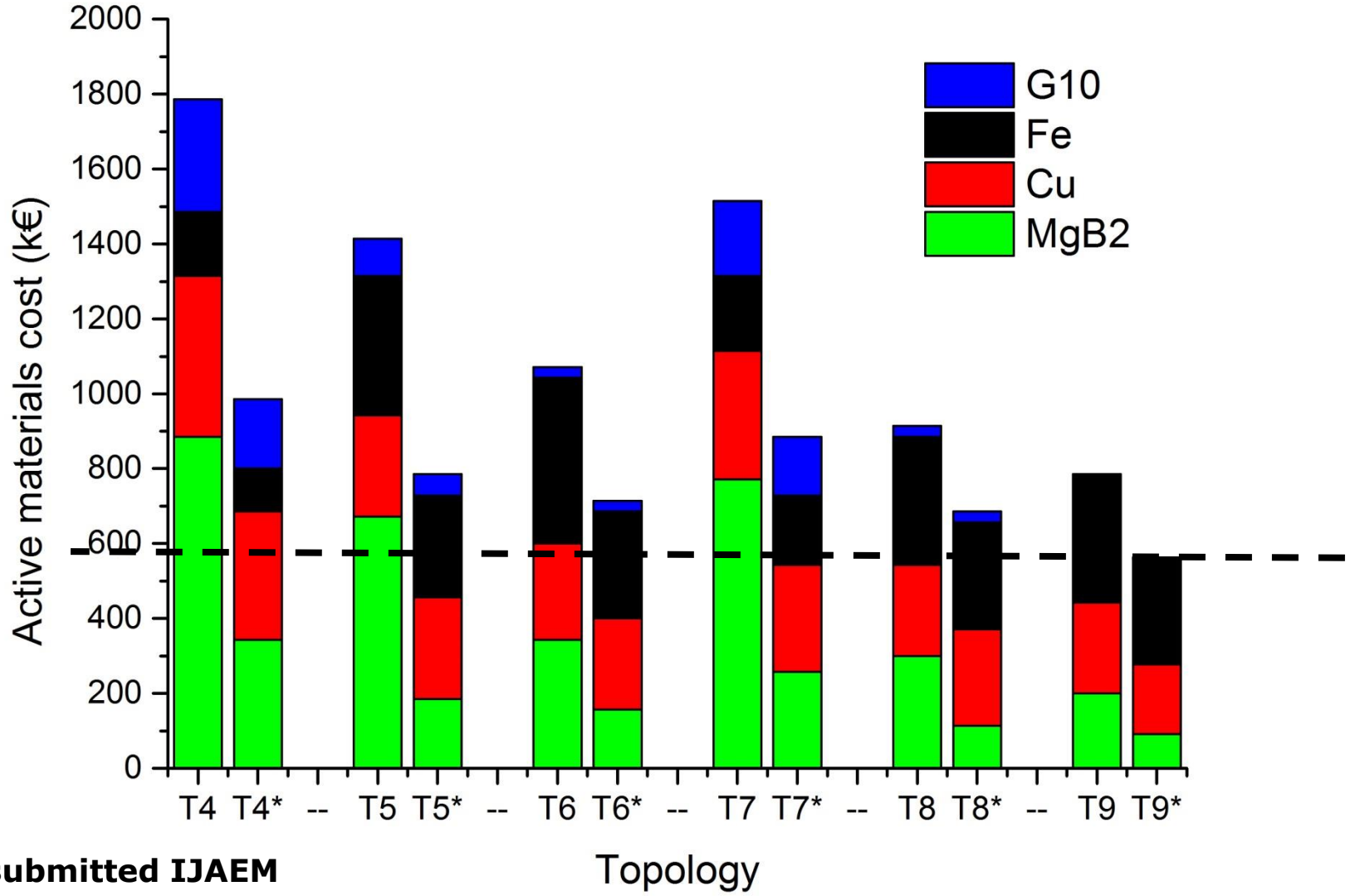
Generator optimization: Operation point



10 MW generator optimization D = 6.0 m



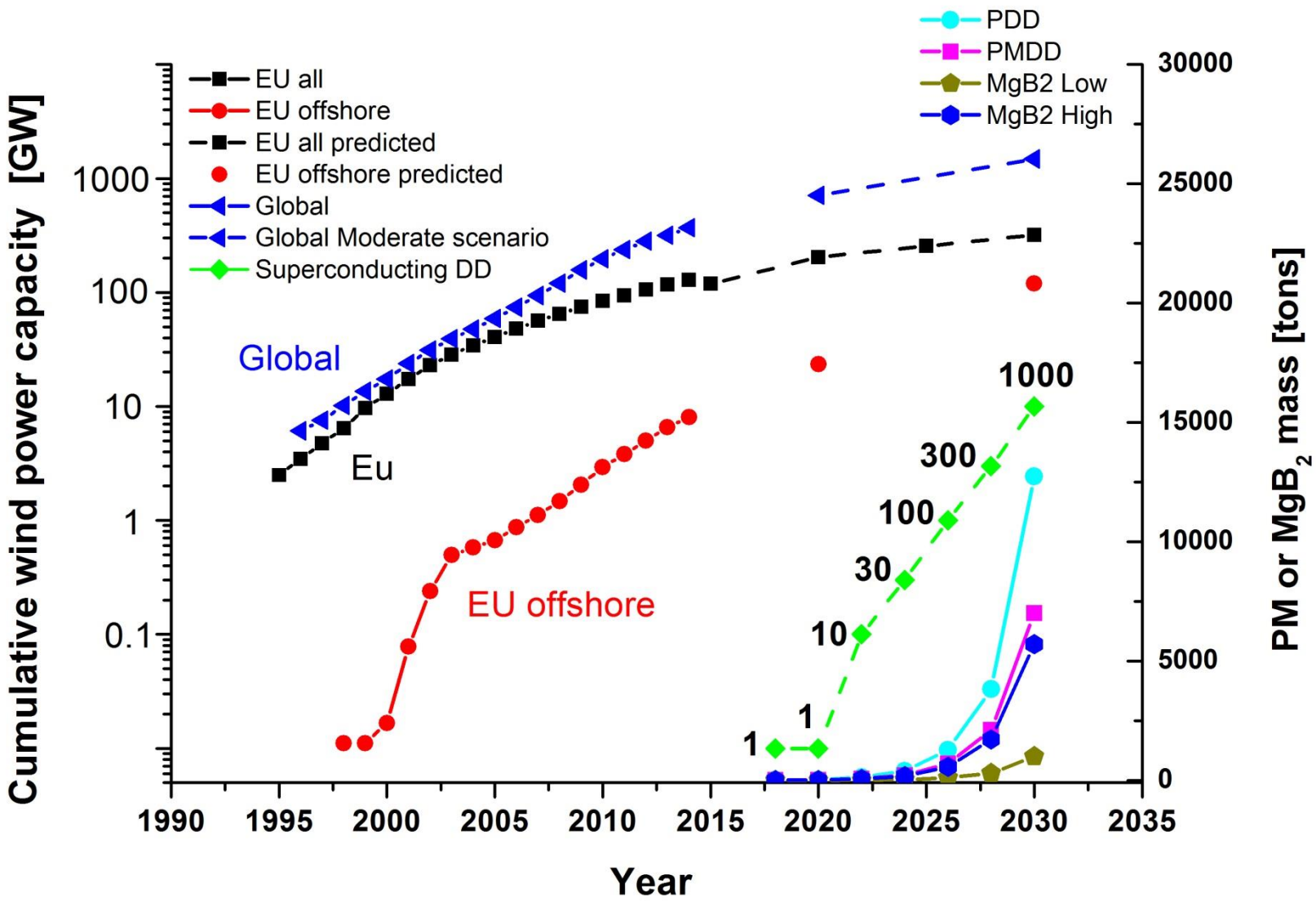
Active material cost: MgB_2 4 €/m → 1 €/m



Permanent Magnet Direct Drive

D. Liu *et. al.*, submitted IJAEM

Roadmap to 10 GW SCDD



Wire use 10 MW(GW) MgB_2Gen

100 km (Mm)

5000 km/year ↑ ☹

f_{CAPEX} ~ 1-2% ☺

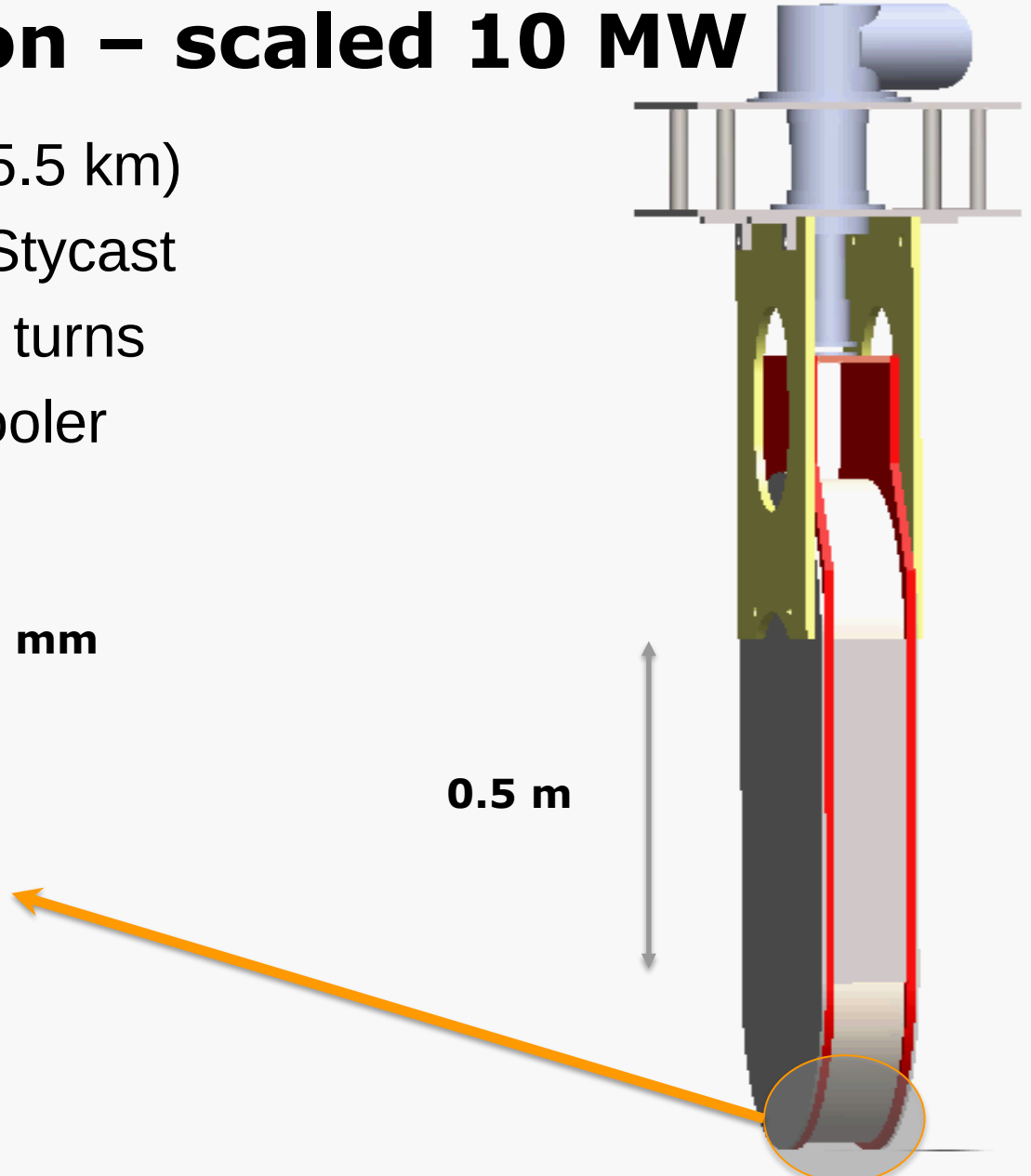
T = 10-20 K ☺

First attempt to include cryogenic cooling resulted in an INNWIND.EU Levelized Cost of Energy change of a jacket mounted 10 MW turbine in 50 m of water of:

$$\Delta LCoE \sim -0.4\,\%$$

MgB_2 field coil demonstration – scaled 10 MW

- Tape Columbus Superconductors (5.5 km)
- Kapton insulation & wet winding in Stycast
- 10 double pan-cake coils of 2 x 100 turns
- Cooling to T = 10-20 K using cryocooler
- $B_{end,max}$ ~ 2.8 T & B_{center} ~ 1 T



Conclusion

- MgB_2 Direct Drive as alternative to Permanent Magnet Direct Drive
- No dependence on Rare Earth Elements (Nd, Pr, Dy) for $R_2Fe_{14}B$ magnets
- Philosophy: “Put as much iron as possible into generator”
  - Active material cost (SC, PM, Fe, Cu) very similar to PMDD
  - First INNWIND.EU turbine + foundation estimate $\Delta LCoE \sim -0.4\,\%$
- MgB_2 wire supply chain basically ready for 10 GW MgB2 SCDD by 2030
- Demonstrate MgB_2 field coil technologies → Reliability & Availability ?

INNWIND.EU Collaborators in Workpackage 3 on Electromechanical Conversion

- **Asger B. Abrahamsen (asab@dtu.dk)**
  - **DTU Wind Energy (DK)**
- **Dong Liu & Henk Polinder**
  - **Delft University of Technology (NL)**
- **Niklas Magnuson**
  - **SINTEF (N)**
- **Ewoud Stehouwer & Ben Hendriks**
  - **-DNV GL (NL)**
- **Arwyn Thomas**
  - **Siemens Wind Power (DK)**

Project website: www.innwind.eu