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Publication date:
2015

Document Version
Peer reviewed version

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Citation (APA):

Abrahamsen, A. B., Liu, D., Magnusson, N., & Polinder, H. (2015). Potential of MgB₂ superconductors on direct drive generators for wind turbines European Wind Energy Association (EWEA). [Sound/Visual production (digital)]. EWEA Annual Conference and Exhibition 2015 , Paris, France, 17/11/2015

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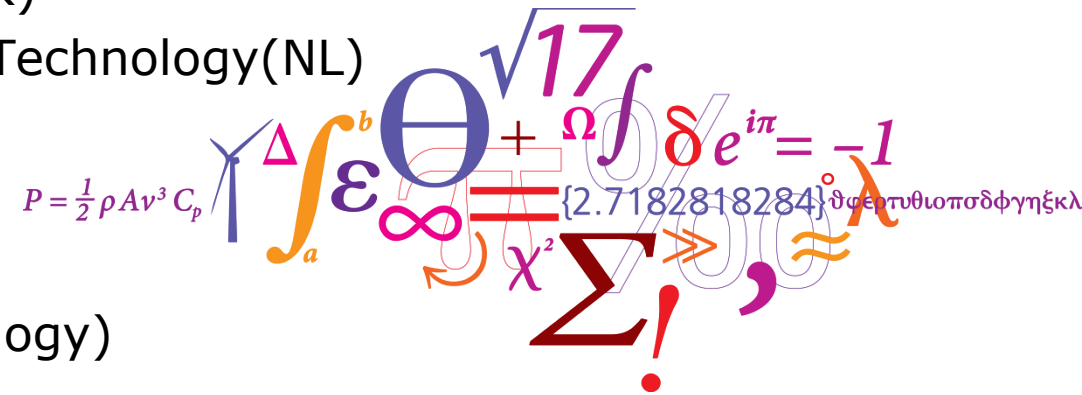
Potential of MgB₂ superconductors on direct drive generators for wind turbines

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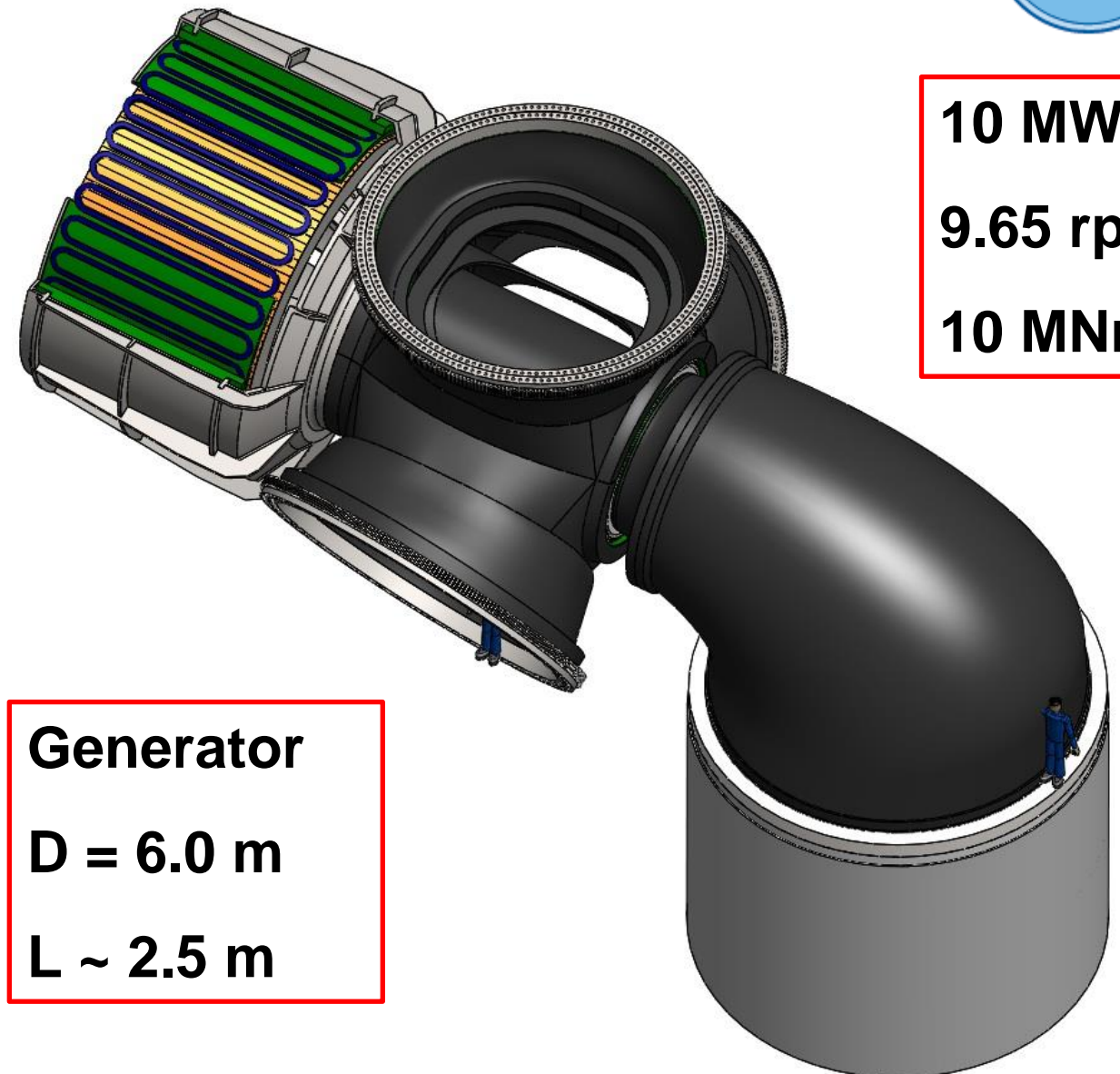
Innovation in wind turbine drive trains (Turbine technology)

Thursday 19 November 2015 14:30-16:00

EWEA 2015, Paris

Outline

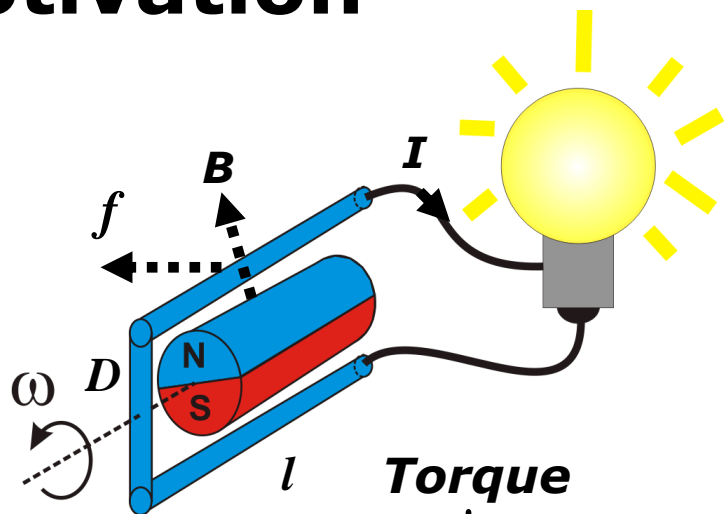
- Motivation
- Design philosophy
- Generator optimization
- Active material cost
- Road map for 10 GW
- Conclusion



10 MW
9.65 rpm
10 MNm

Generator
D = 6.0 m
L ~ 2.5 m

Motivation



$$\text{Power} \propto BI D^2 l \omega$$

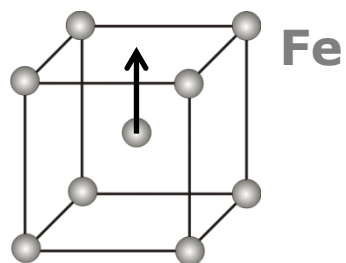
1G : Copper coils + Iron

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

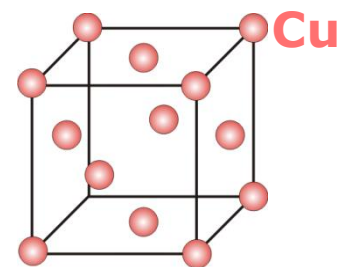
10 MW ~ 6 tons PM

3G : MgB_2 coils + Fe

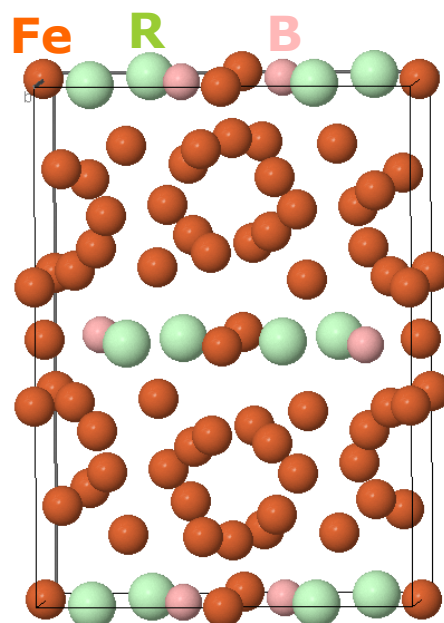
10 MW ~ No Rare Earth



$T_C = 770 \text{ }^\circ\text{C}$

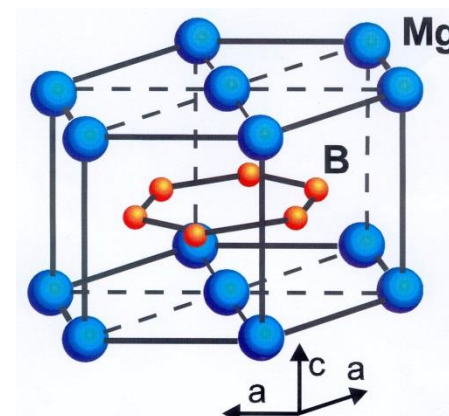


$J \sim 2 \text{ A/mm}^2$



$T_C = 310 \text{ }^\circ\text{C}$

$B_r \sim 1.4 \text{ T}$



$T_C = -234 \text{ }^\circ\text{C}$

$B_{c2} \sim 40 \text{ Tesla}$

$J < 10000 \text{ A/mm}^2$



Columbus wire

0.7 mm

3.0 mm

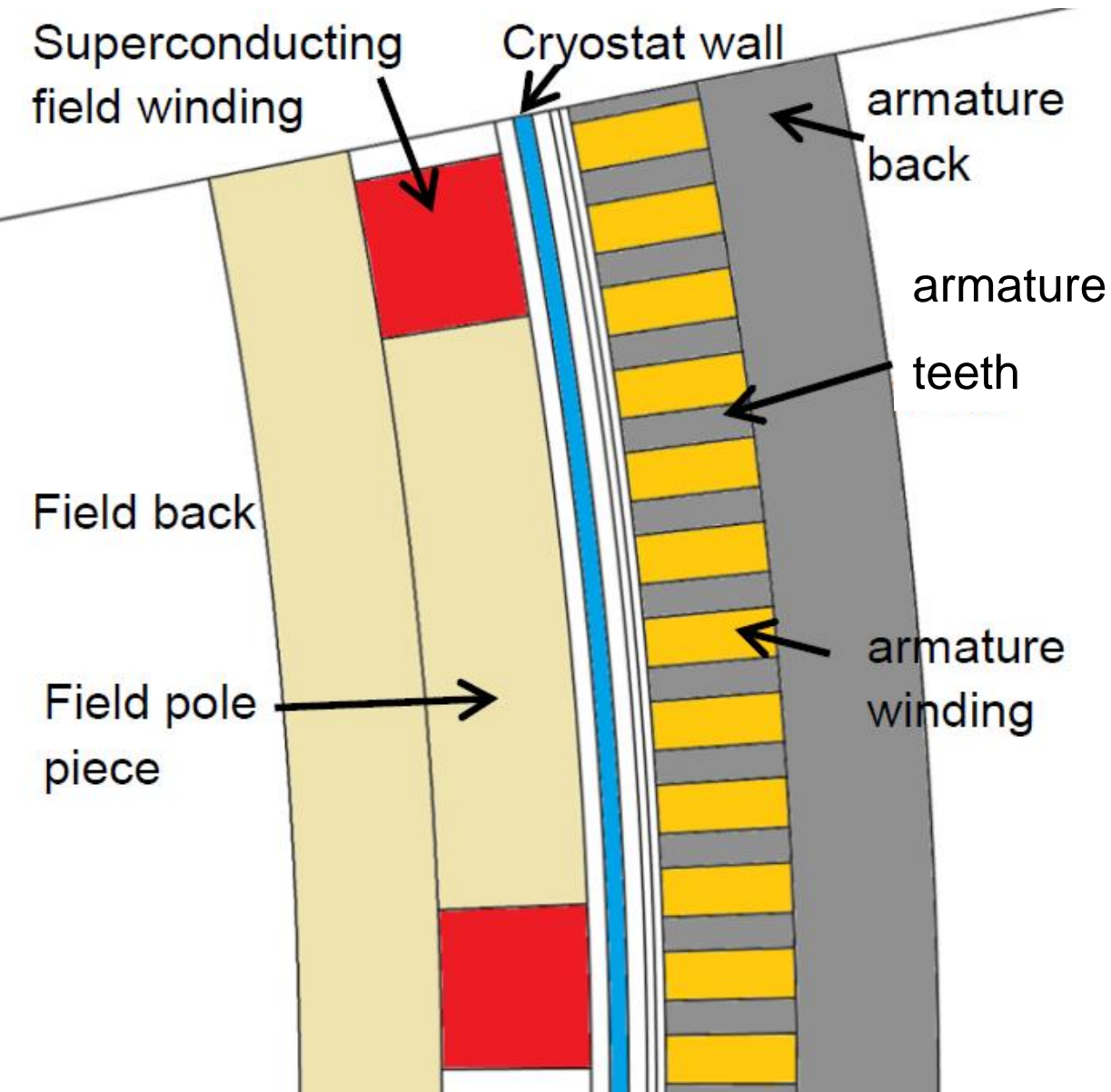


20 Sept

Cu

Ni

Best topology for MgB₂ wires in WTG?

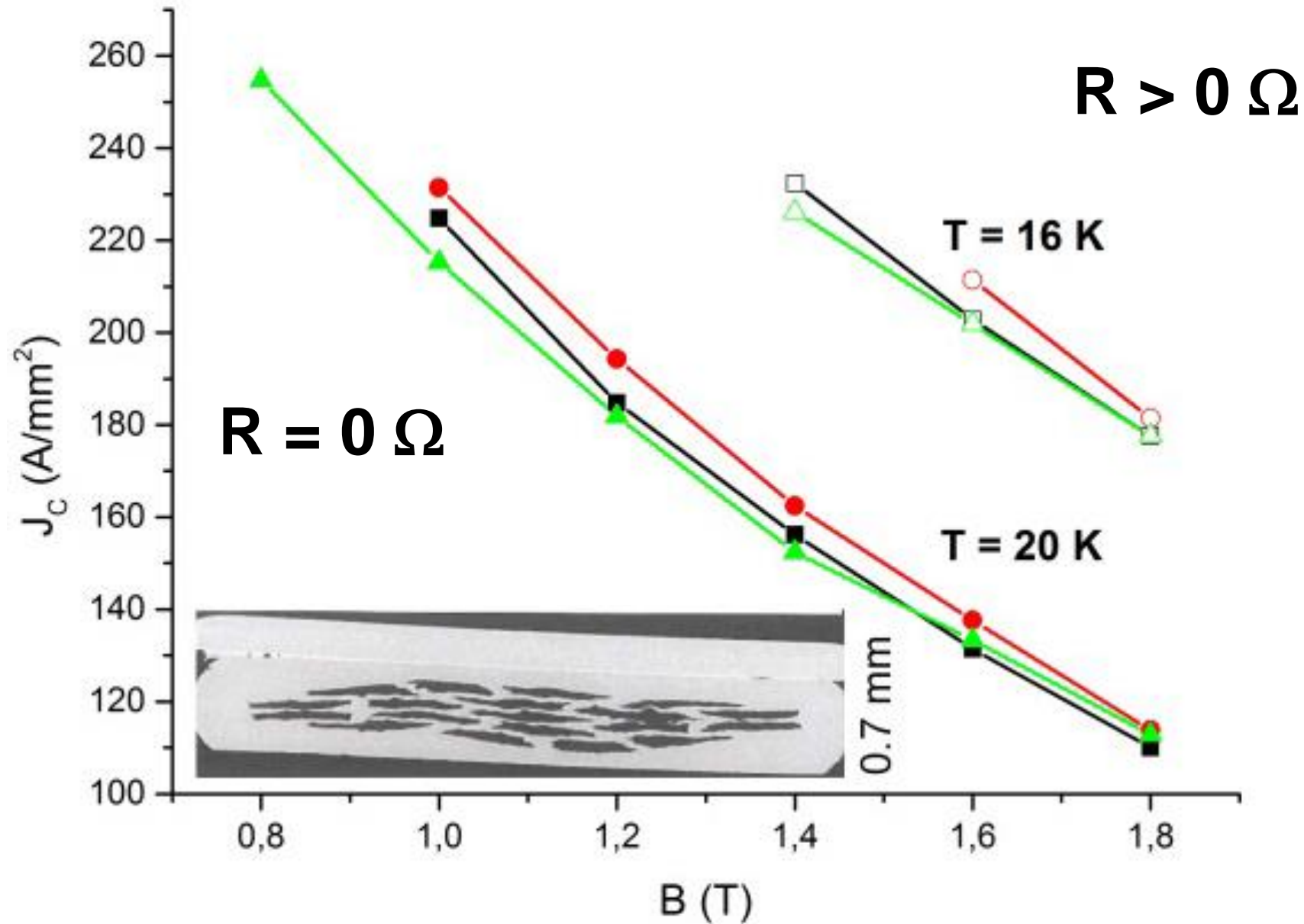


Design philosophy:

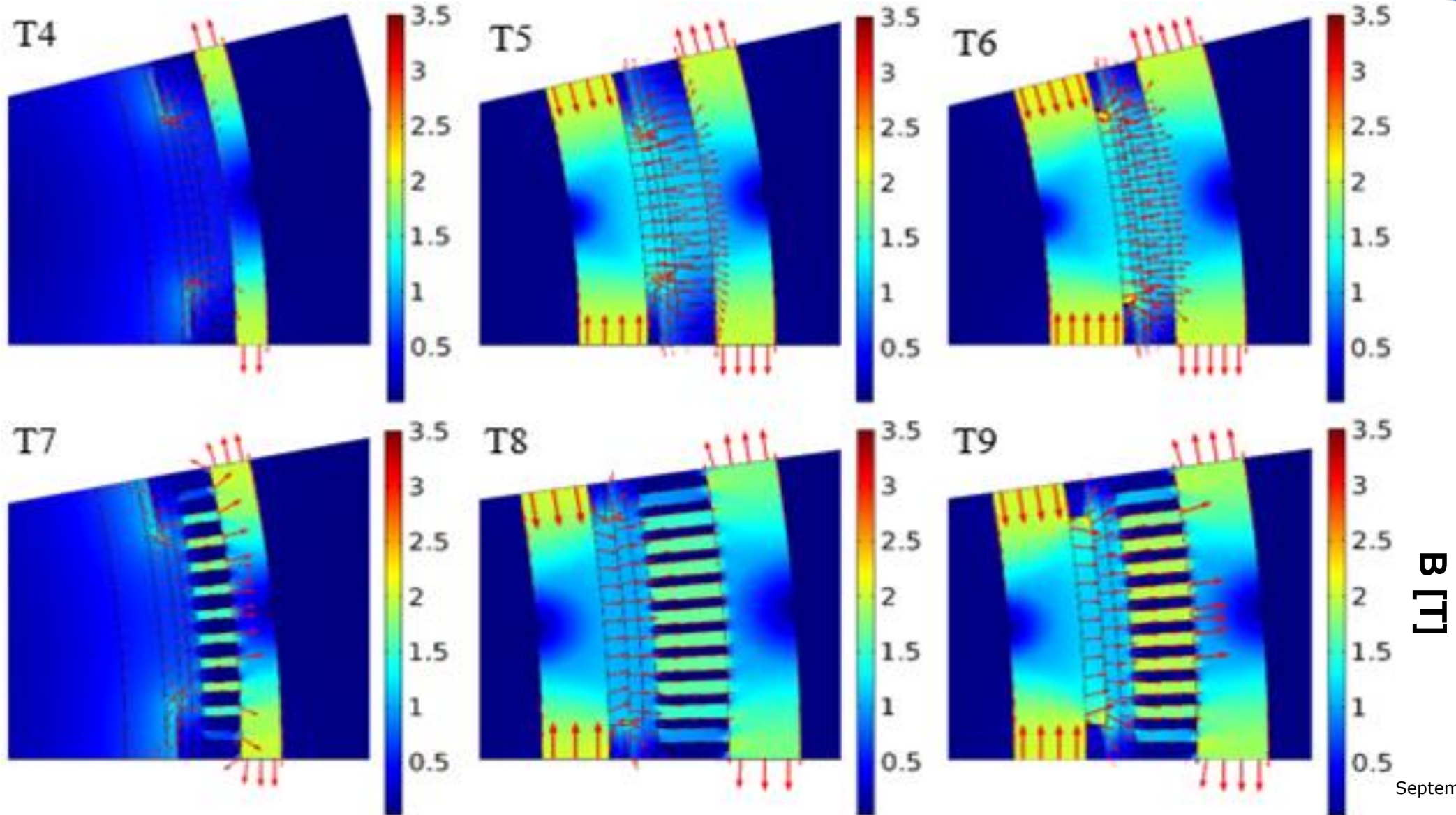
Put as much iron as possible to minimize magnetic flux path

| | |
|-------------------------|-------------------|
| MgB₂: | 4 €/m |
| Fe: | 3 €/kg |
| Cu: | 15 €/kg |
| G10: | 15 €/kg |
| PM: | 50-75 €/kg |

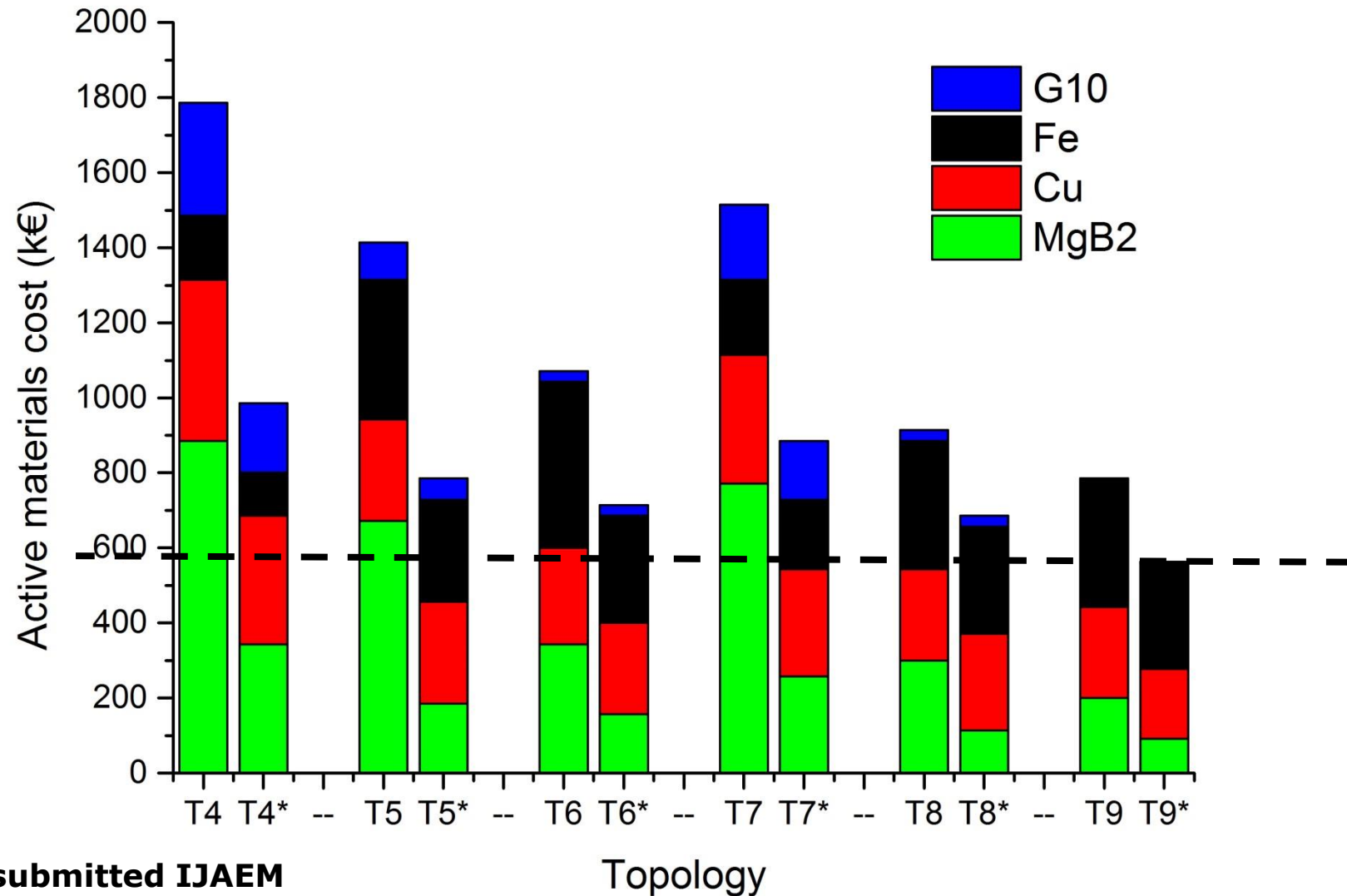
Generator optimization: Operation point



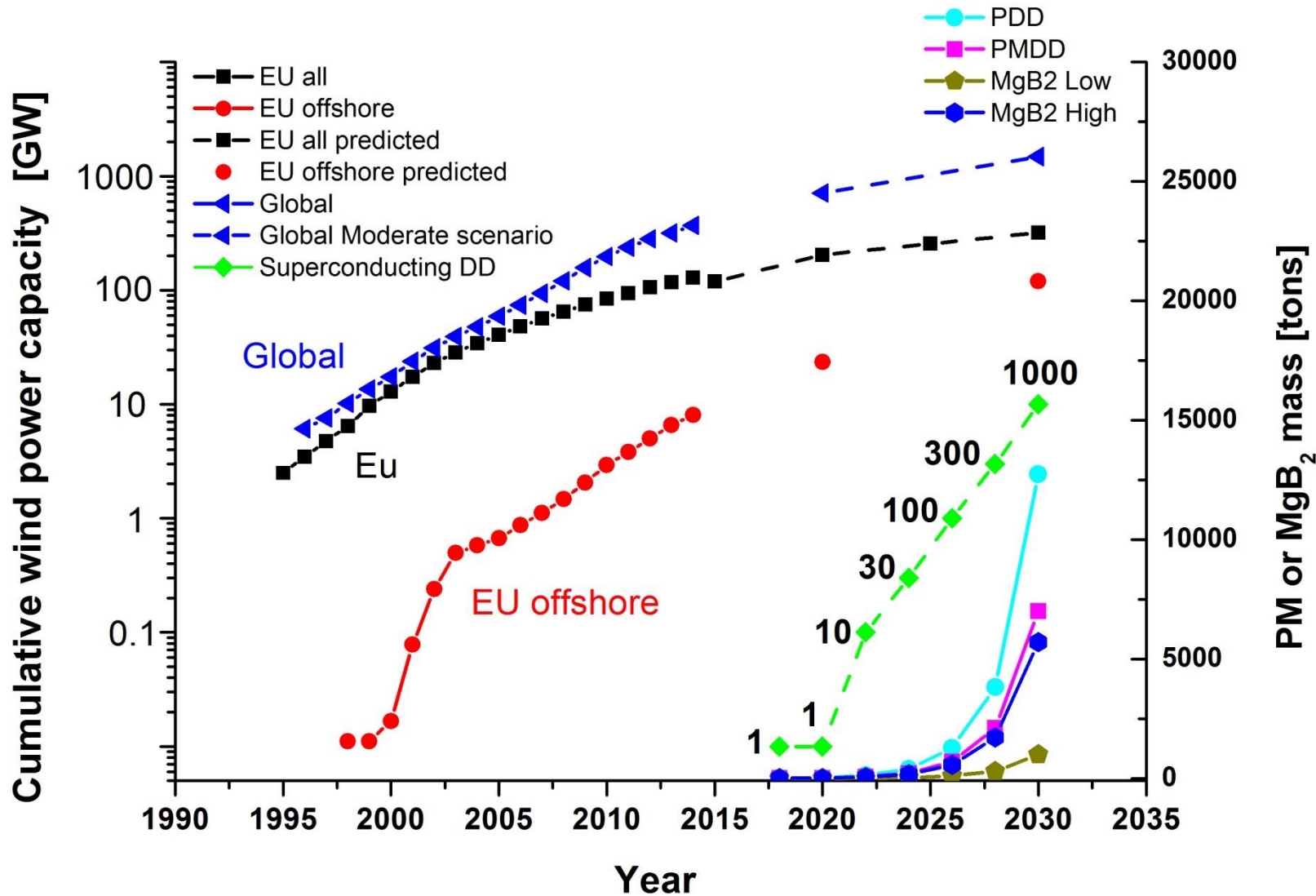
10 MW generator optimization D = 6.0 m



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



Roadmap to 10 GW SCDD



Wire use 10 MW(GW) MgB₂Gen

100 km (Mm)

5000 km/year ↑

$f_{CAPEX} \sim 1-2\%$

$T = 10-20\text{ K}$



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:

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

MgB₂ 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 $T = 10\text{-}20\text{ K}$ using cryocooler
- $B_{\text{end,max}} \sim 2.8\text{ T}$ & $B_{\text{center}} \sim 1\text{ T}$

0.7 mm



3.0 mm

0.5 m



Conclusion

- **MgB₂ Direct Drive as alternative to Permanent Magnet Direct Drive**
- **No dependence on Rare Earth Elements (Nd, Pr, Dy) for R₂Fe₁₄B 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 $\Delta LCoE \sim - 0.4 \%$**
- **MgB₂ wire supply chain basically ready for 10 GW MgB₂ SCDD by 2030**
- **Demonstrate MgB₂ field coil technologies → Reliability & Availability ?**

INNWIND.EU Collaborators in Workpackage 3 on Electromechanical Conversion



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- **Niklas Magnuson**
 - SINTEF (N)
- **Ewoud Stehouwer & Ben Hendriks**
 - DNV GL (NL)
- **Arwyn Thomas**
 - Siemens Wind Power (DK)

Project website: www.innwind.eu

