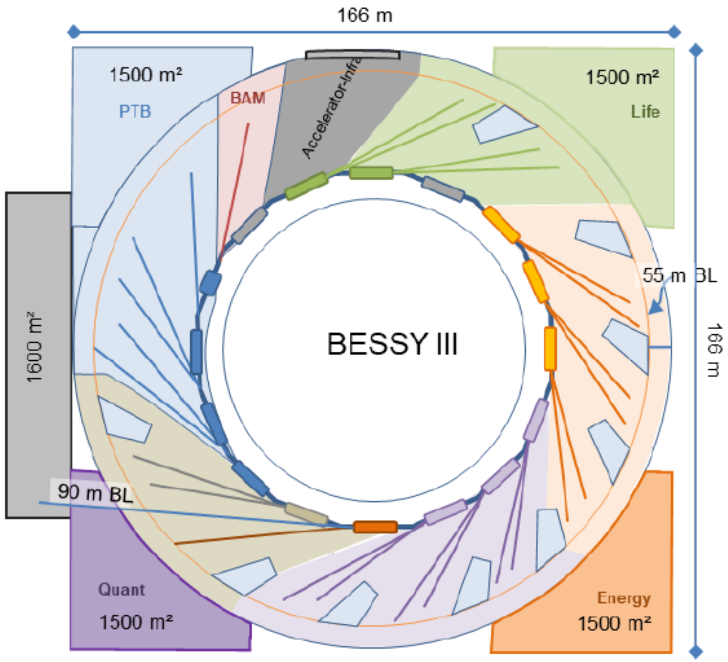
HZB Helmholtz Zentrum Berlin

SUSTAINABILITY PROJECTS FOR BESSYIII

Decreasing the footprint for a new SR facility

Jens Völker

9th LER workshop 2024 CERN



BESSY III (2035)
-> MBA (6BA) lattice (16 arcs)
-> ~340m circumferance
-> hor. emittance <100pmrad
-> energy 2.5GeV
-> up to 500mA beam current

PTB/BAM metrology applications

-> Metrology source Homogenous bends

Variation of Magnetic field at source point (10x10x10mm3) <1 unit

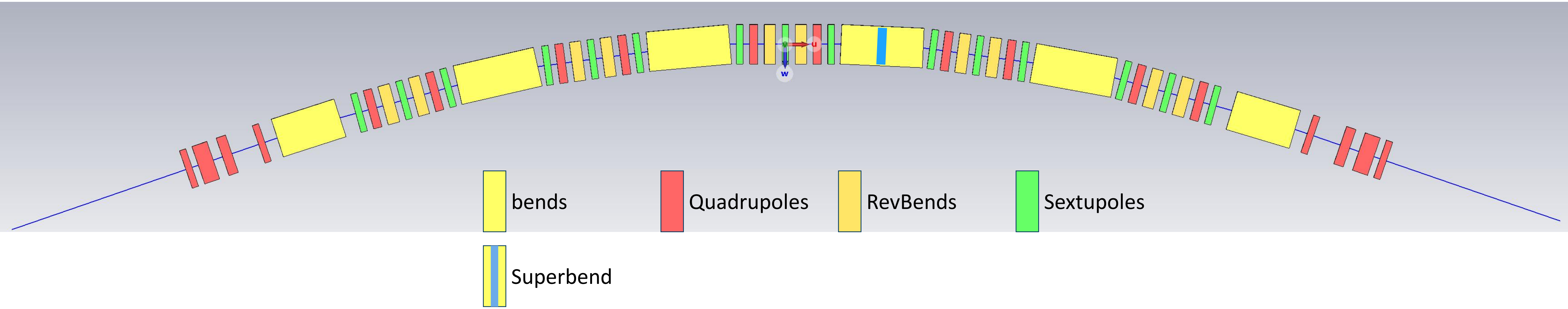
Option for one Superbend per arc as hard X-ray source

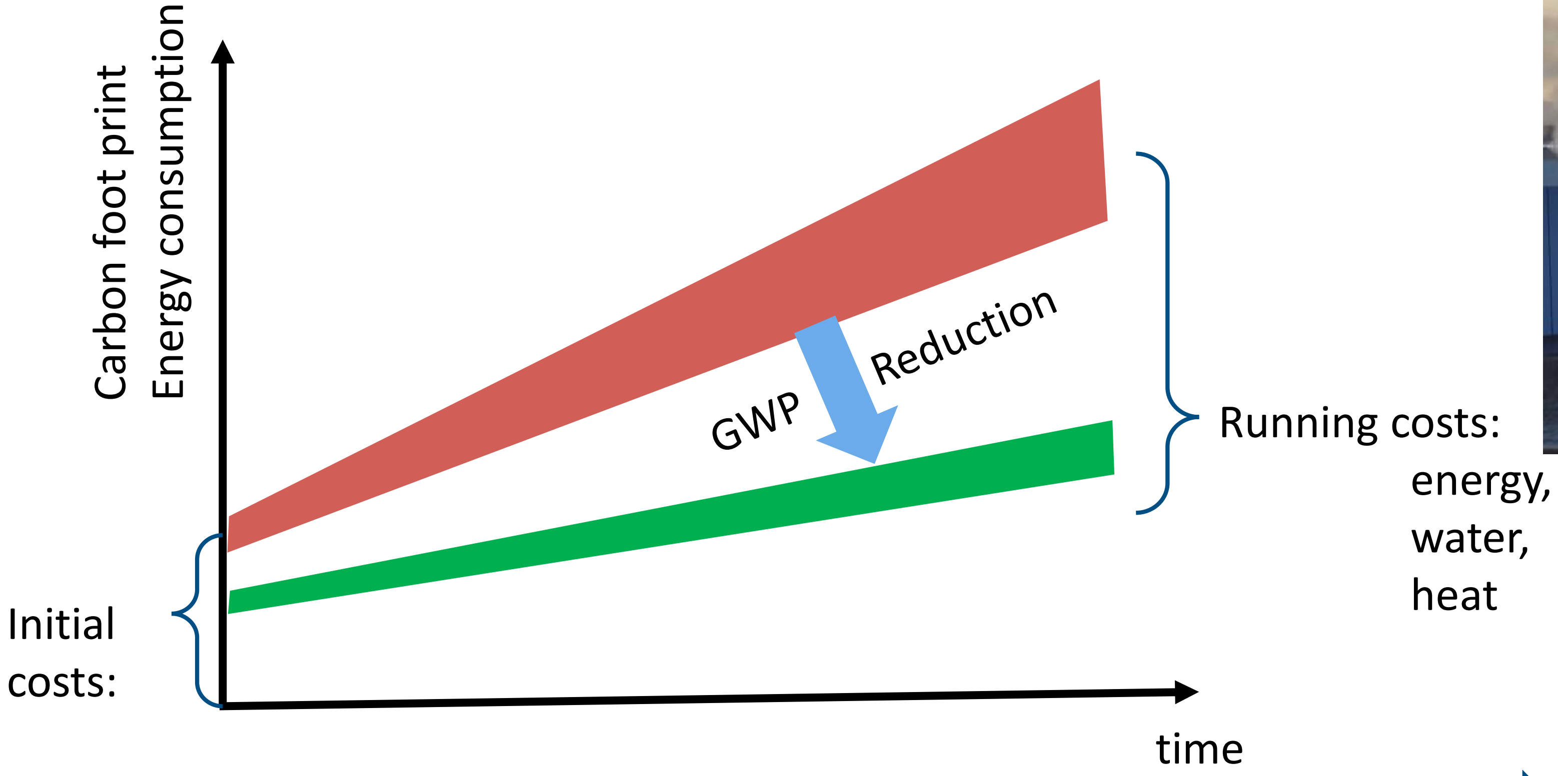
Green field option (BESSYIII / BESSYII):

40% larger circumference
48% higher beam energy
66% higher beam current
>100% larger building complex

Goal for power consumption:

over all power for BESSYIII equal or less than BESSYII !

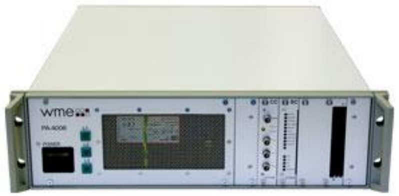




construction
installation
fabrication


https://www.hausjournal.net


Cryoelectra



https://www.wme.de

LCA analyse

OUTLINE:

Building
- -> **concrete construction**
- -> **energy production**

Accelerator Components
- -> **RF hardware**
- -> **magnets**

POSSIBLE ADJUSTMENTS IN THE CONSTRUCTION PHASE

- **material-optimized construction**
  e.g. use of carbon concrete to save concrete, which must have minimum coverings to protect the conventional reinforcing steel from corrosion

- **optimized construction shape**
  optimize shape and cross section of the ground plate
  for high stiffness and vibration dampening, but less concrete

-> ca. 29000m^3 concrete -> ca. 70000t

CO_2 emmission concrete (t)	ca. 42000
CO_2 emmission steel (t)	ca. 9500

-> different cross sections and material distributions to minimize concrete

Example: Cube in Dresden - the world's first building made of carbon concrete
(from: www.bba-online.de/news/cube-neues-bauen-mit-carbonbeton/#slider-intro-1)

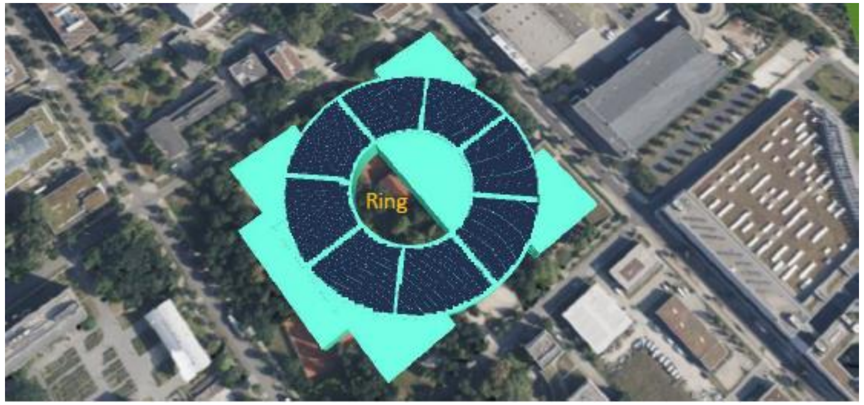
Comparison reinforcing carbon and steel
(from https://www.carbocon.de)

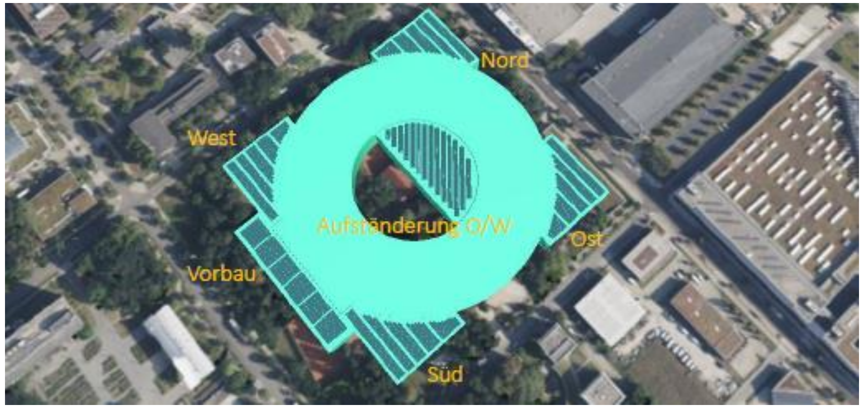
POSSIBLE ADJUSTMENTS IN OPERATION PHASE USE OF PHOTOVOLTAICS

Energy generation of the building

- Energy-harvesting potential by PV-skin: 1–3 GWh/a

  Assuming a realistic improvement in PV efficiency of around 10%: **3 GWh/a**





PV-facade study

-> 360 commercial solar modules
-> installed on three sides of the building
-> 28 MWh per year
-> 120 measurements points and sensors und

Accelerator Running Costs

RF-components

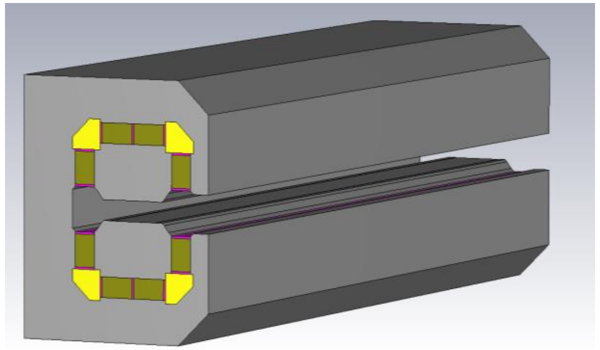
500MHz SSA

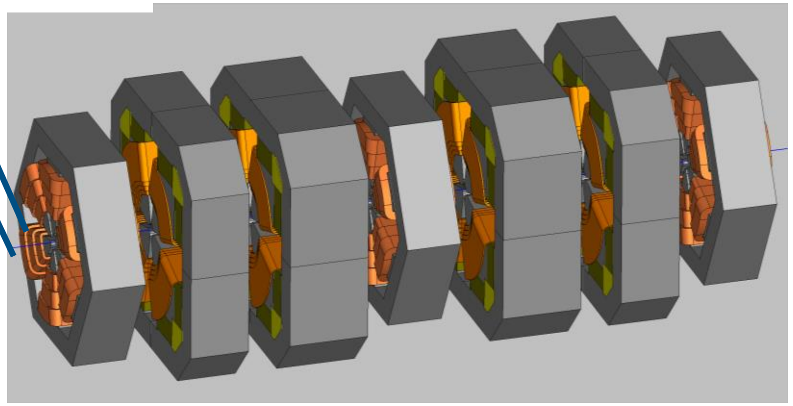
Cryoelectra

500MHz Cavities at BESSYII

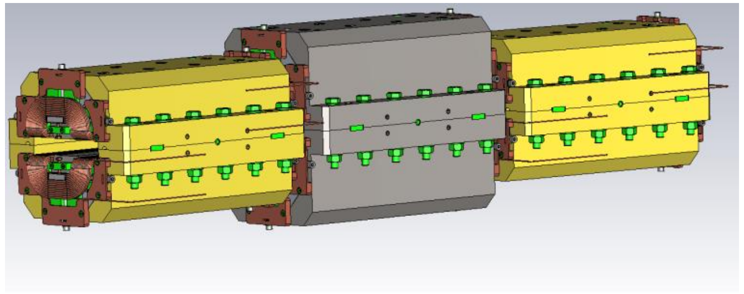
Magnet system

PM Bending magnet for BESSYIII





Magnet setup of an unit cell for BESSYIII (4 of 7 magnets are PM)



PM Triplet for BESSYII to replace a 20kW dipole

RF 2.0 Project (EU Horizon 2023/2024) „Research Facility 2.0“

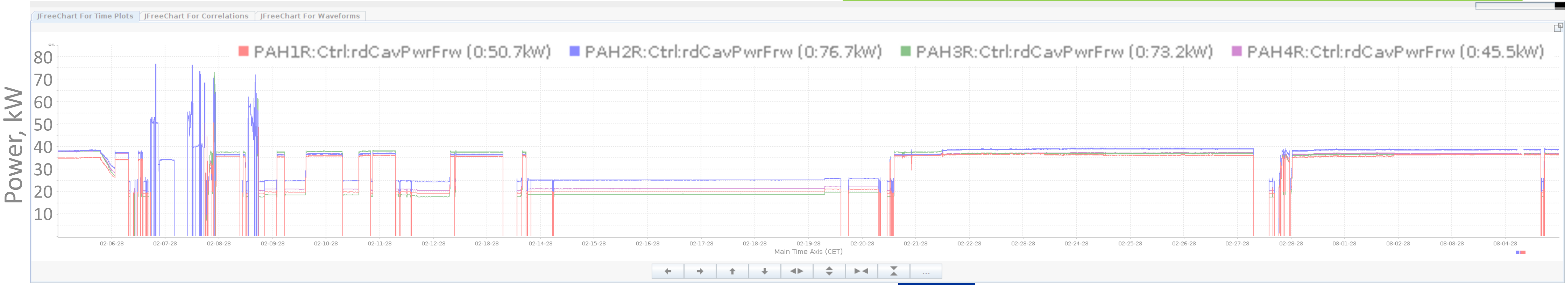
PM Workpackage 2.2
partners: **ALBA, Commtia, Cryoelectra, HZB**
main topics:

⇒ **prototyping of optimized Solid State Amplifier (SSA) systems by changing the operational parameters of RF-transistors for 1.5 GHz (ALBA) and 500MHz (HZB)**
⇒ for highest efficiency under varying load conditions

SSA ALBA+HZB by Commtia + Cryoelectra

-> adaptive adjustment of the amplifier’s compression point for maximum efficiency at variable RF output levels
-> an appropriate interface from the accelerator control system to SSA
-> design of an Active Parametrization Digital Control (APDC) for a 1.5GHz SSA
-> Non Linear Solid State Amplifier Board for a 1.5GHz

Courtesy A. Matveenko (HZB)

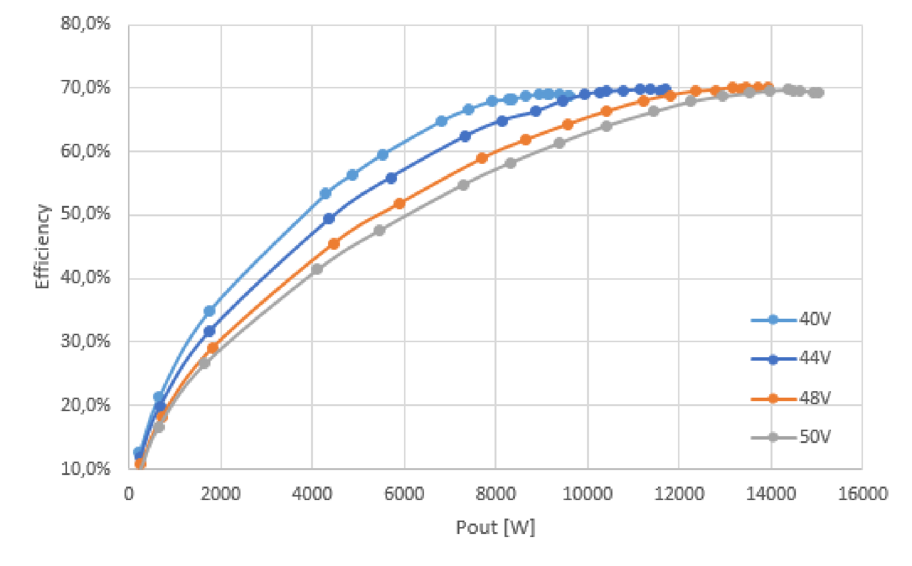


This project has received funding from the European Union’s Europe research and innovation program under grant agreement **No 101131850**

RF 2.0 Project (EU Horizon 2023/2024) „Research Facility 2.0“

RF Technology for Particle Accelerators and Fusion *Cryoelectra*

Effect of drain voltage on efficiency



- By adjusting the bias point, the efficiency can be optimized for lower output powers
- Setting the right bias point dynamically requires intricate knowledge of the whole amplifier system
- This process shall be automated by the proposed control algorithm to make the efficiency improvements usable by the accelerator’s operator

Courtesy B. Nordmann (Cryoelectra)

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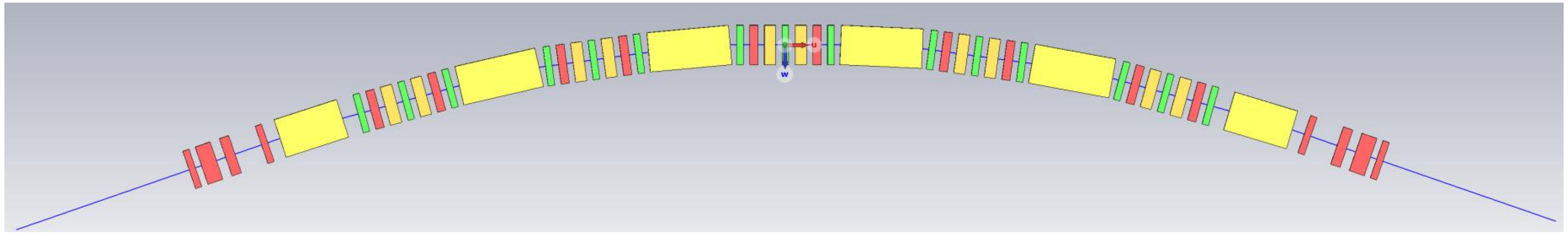
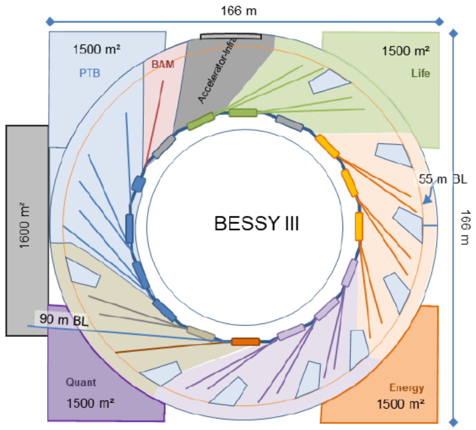
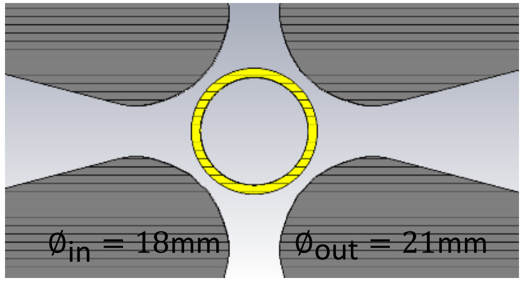
MAGNETS OVERVIEW



Quadrupoles | Homogenous bends | Reverse bends | Sextupoles



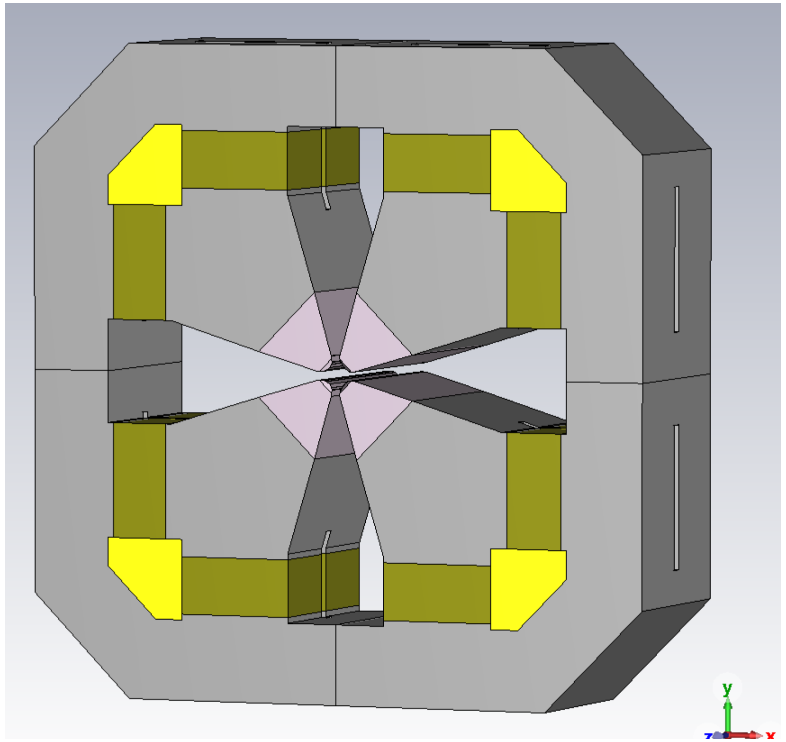
min. aperture radius for all magnets: 12.5mm



	Dipole	Quadrupole	Reverse Bends	Sextupole
Field/gradient (def. Limits)	0.6-0.8 T (1.3 T)	50-90 T/m (80 T/m)	80 T/m and (0.18-0.22) T (30 T/m and 0.8 T)	<4000 T/m² (4000 T/m²)
Quality	$0.1 \cdot 10^{-4}$	$\sim 1 \cdot 10^{-4}$	$\sim 1 \cdot 10^{-4}$	tbd
Stability	$<1 \cdot 10^{-4}$			
Variation	-	10%	5%	100%
Power consumption (PM / electro)	**0 kW / 290 kW**	**<50 kW / >400 kW**		**>100 kW**

1. Strong magnetic fields -> high magnetic field energy / **electric power**
2. High field Quality -> high mechanical and alignment precision
3. Stable field operation -> minimization of ripple and vibrations
4. Small parameter Variation -> constant magnet operation next to design value

RF 2.0 Project (EU Horizon 2023/2024) „Research Facility 2.0“

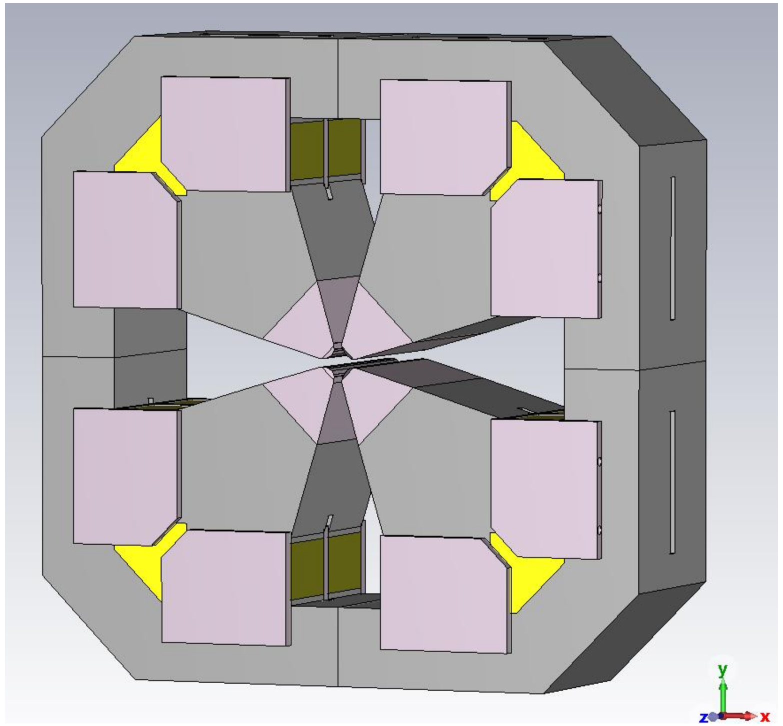


-> PM driven QP magnet with CoFe Pole Shoes (gradient up to 120T/m)

-> Pole Shoe Tip and chamfer are numerical optimized to maximize b2 (quadrupole) and to minimize central and/or integrated b6, b10 and b14

-> up 24 tuning plates (10mm thick CoFe) will be installed in parallel to PM blocks

-> position of plates reduces the max. magnetic flux (short circuit)



-> the plates are mechanical connected

-> position inside yoke can be changed via motors (slow)

-> field strength can be reduced by approx. 40% ($\sim 0.5\%/\text{mm}$)
(or $\pm 20\%$ to operating point)

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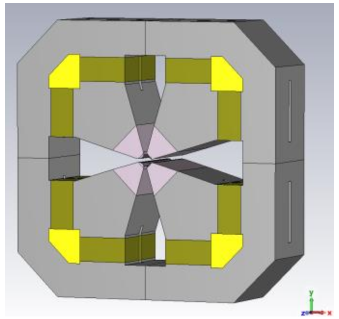
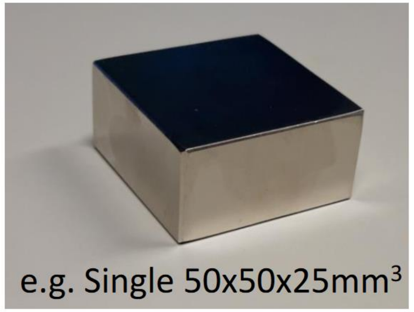
PM based Magnets

Yoke

PMs → NdFeB, SmCo

Thermal shims





Yoke

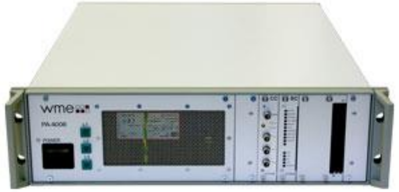
Coil

Power Supply

Cables

Cooling lines

Courtesy A. Vorozhtsov (MAX IV)



Resistive Magnets

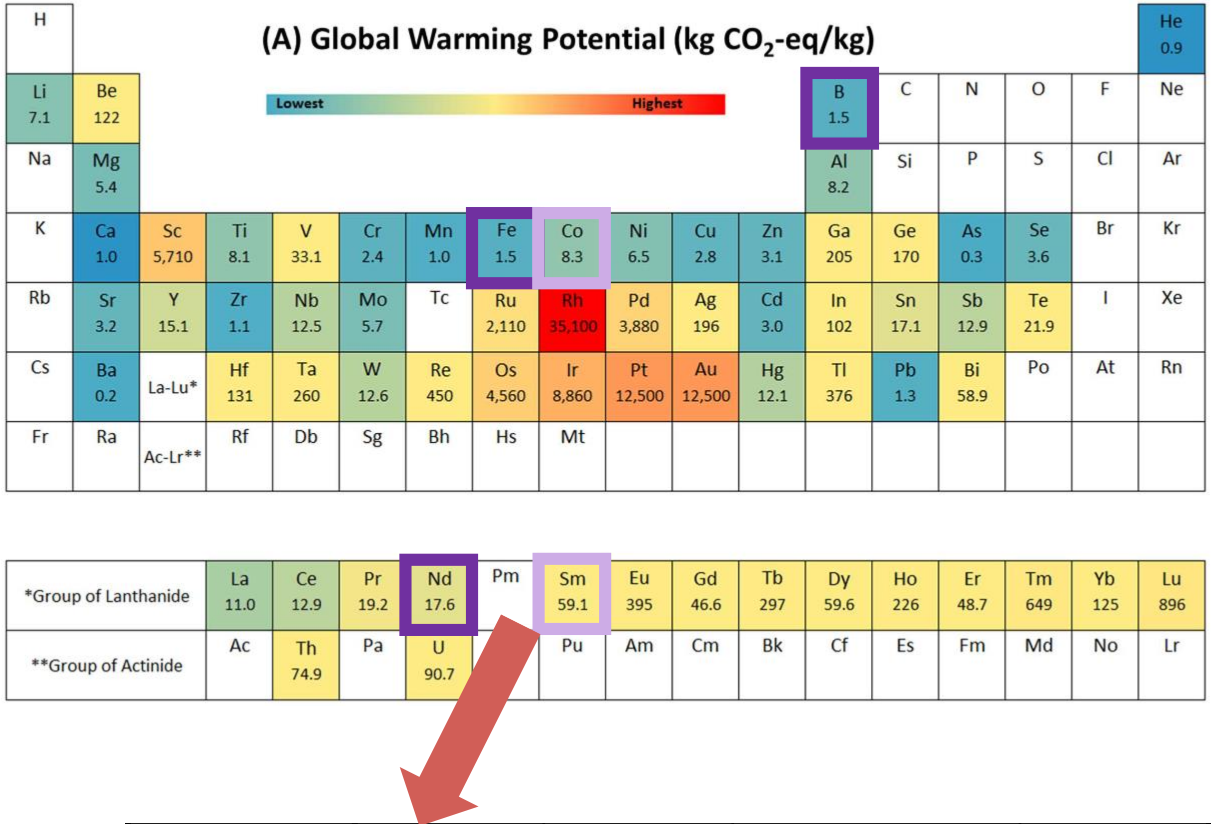
Fabrication costs

e.g. PM blocks

GWP parameter for nearly all materials:

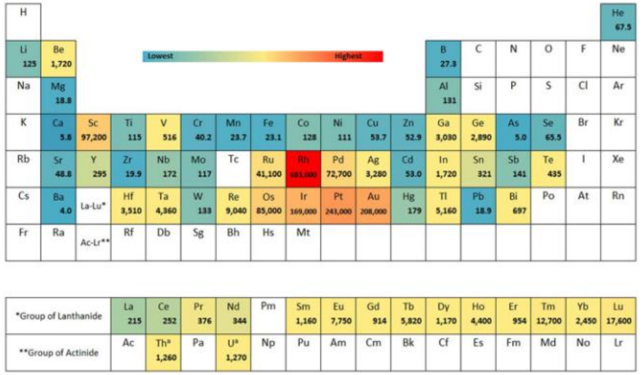
-> mining, concentration, purification, refining

-> PM fabrication processes have to concisder separately

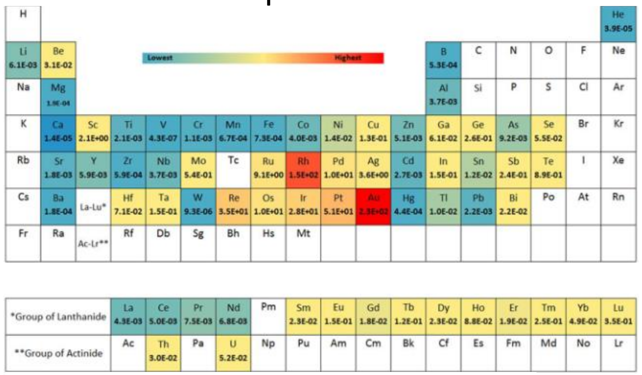


PM material 1 kg	GWP CO_2-eq	Energy MJ-eq	Freshwater eutrophication kg P-eq	Human Toxicity CTUh
$Nd_2Fe_{14}B$	5.79	108.8	0.0023	2.51E-06
$SmCo_5$	25.46	476.7	0.0104	1.18E-05
Sm_2Co_{17}	20.03	366.3	0.0084	9.39E-06

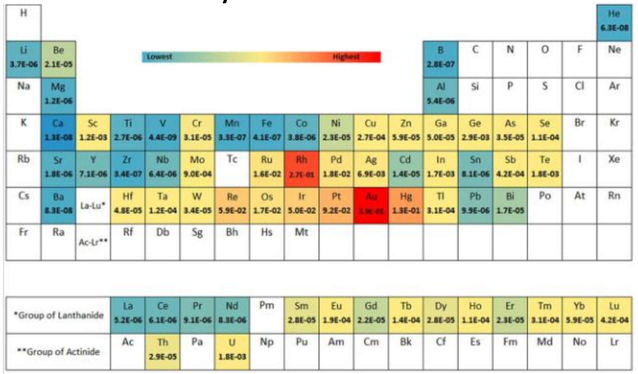
Cumulative Energy Demand:



Freshwater Eutrophication:



Human Toxicity:



BUT:

several databases (countries, technology, etc.) with extremely different values!

e.g. NdFeB GWP:

B. Sprecher[1]: 21-41kg CO_2-eq

NEOHIRE D5.4 Report[2]: 89kg CO_2-eq

I.B.Fernandes[3]: 25-150kg CO_2-eq

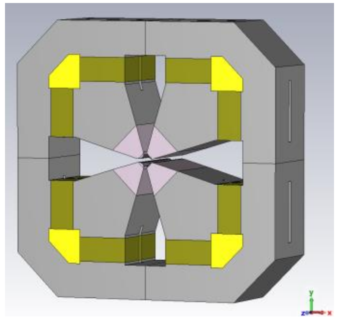
"Life Cycle Assessment of Metals: A Scientific Synthesis"
Philip Nuss, Matthew J. Eckelman *(journals.plos.org/) [4]*

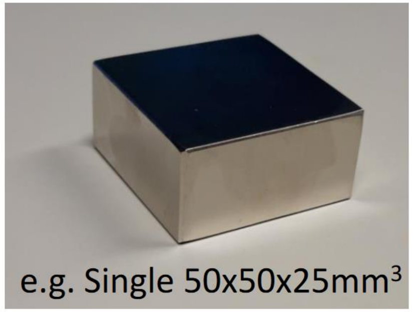
Yoke →

PMs → NdFeB / SmCo

Thermal shims →

PM based Magnets





LCA parameter	SmCo	NdFeB
GWP (CO_2 eq)	**20-70**	**20-150**
Energy product kJ/m^3	**160-260**	**250-400**
Thermal stability	**-0.3e-3/K**	**-1e-3/K**
T_C	**>250°C**	**100°C**
Radiation	**(+)**	**(-)**
Recycling option		**+**

https://www.magreesource.org/
https://www.iwks.fraunhofer.de/en/competencies/MagneticMaterials/Recycling.html

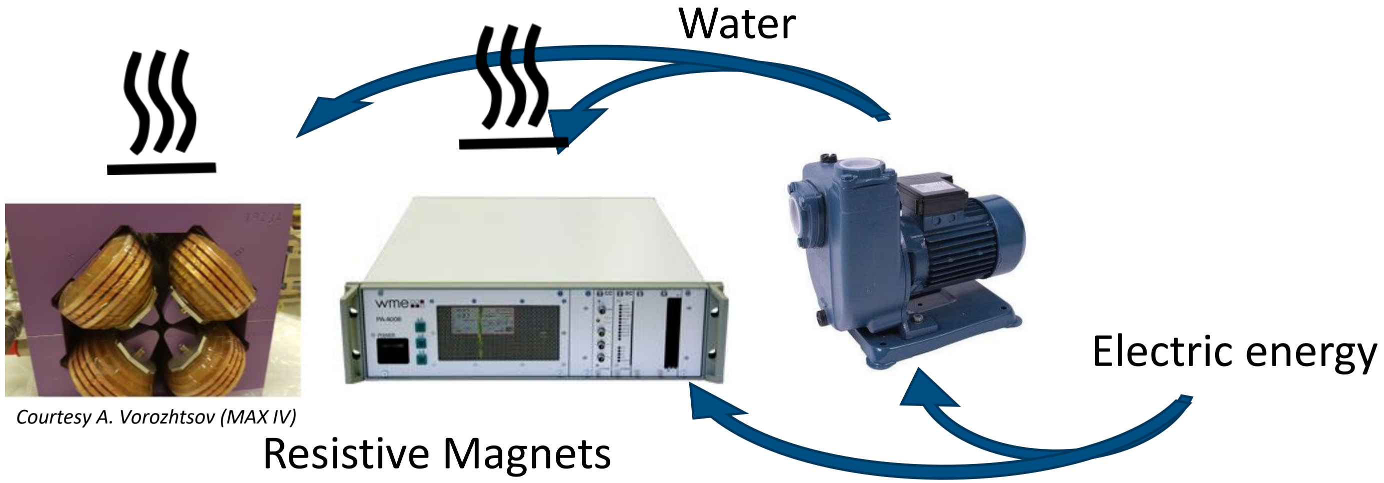
Yoke →

Coil →

Power Supply →

Cables →

Cooling lines →



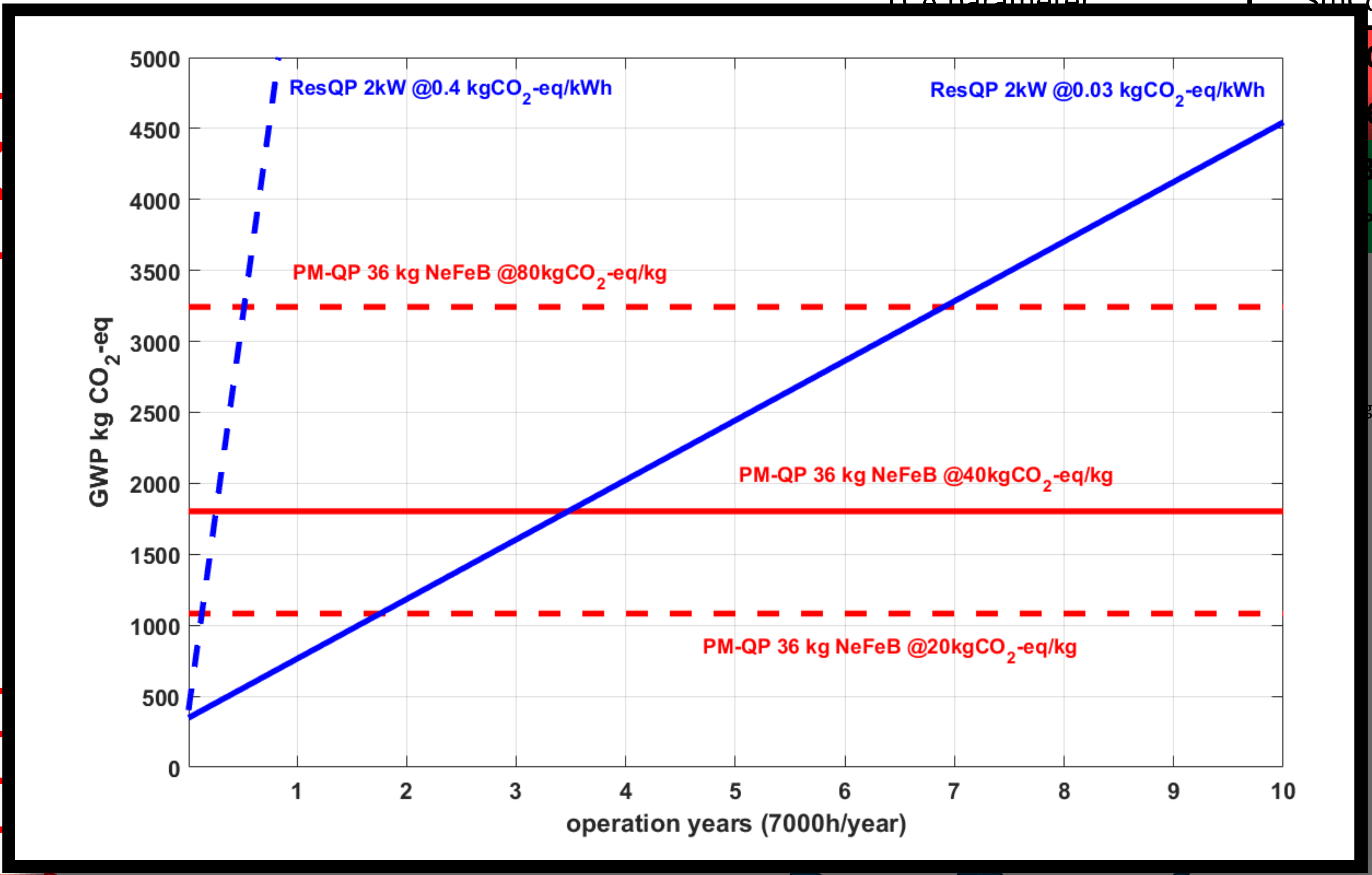
Courtesy A. Vorozhtsov (MAX IV)

Resistive Magnets

Yoke

PMs

Thermal shims



LCA parameter	SmCo	NdFeB
	0	20-150
	60	250-400
	3/K	-1e-3/K
	°C	100°C
		(-)
		+

gneticMaterials/Recycling.html

Yoke

Coil

Power Supply

Cables

Cooling lines

Courtesy A. Vorozhtsov (MAX IV)

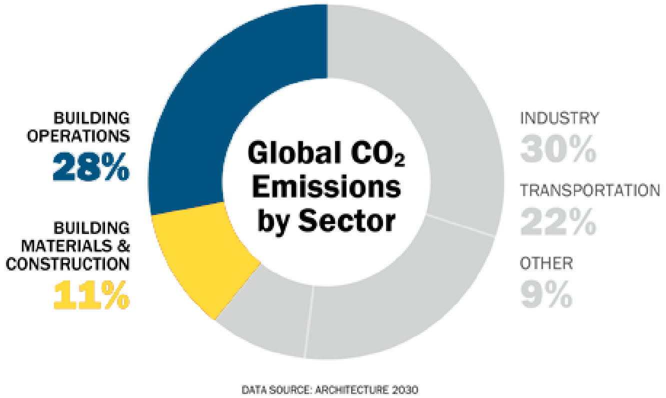
Resistive Magnets

SUMMARY

-> construction work has most impact for initial GWP
-> optimize material consumption

-> decrease running costs
-> install direct energy production

-> clarify material sources to minimize GWP
-> Recycling?



https://www.architects.org/news/the-new-net-zero

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Thank you!

[1] B. Sprecher, *„When materials become critical : lessons from the 2010 rare earth crisis" (2016)*

[2] NEOHIRE, DELIVERABLE D5.4, "*Report on comparative LCA&LCC for NdFeB Permanent Magnet manufacturing processes*" (2019)

[3] I. B. Fernandes, "*Simulation-Based Exergetic Analysis of NdFeB Permanent Magnet Production to Understand Large Systems*" (2020)
https://doi.org/10.1007/s11837-020-04185-6

[4] Nuss et al. „*Life Cycle Assessment of Metals: A Scientific Synthesis*"
10.1371/journal.pone.0101298