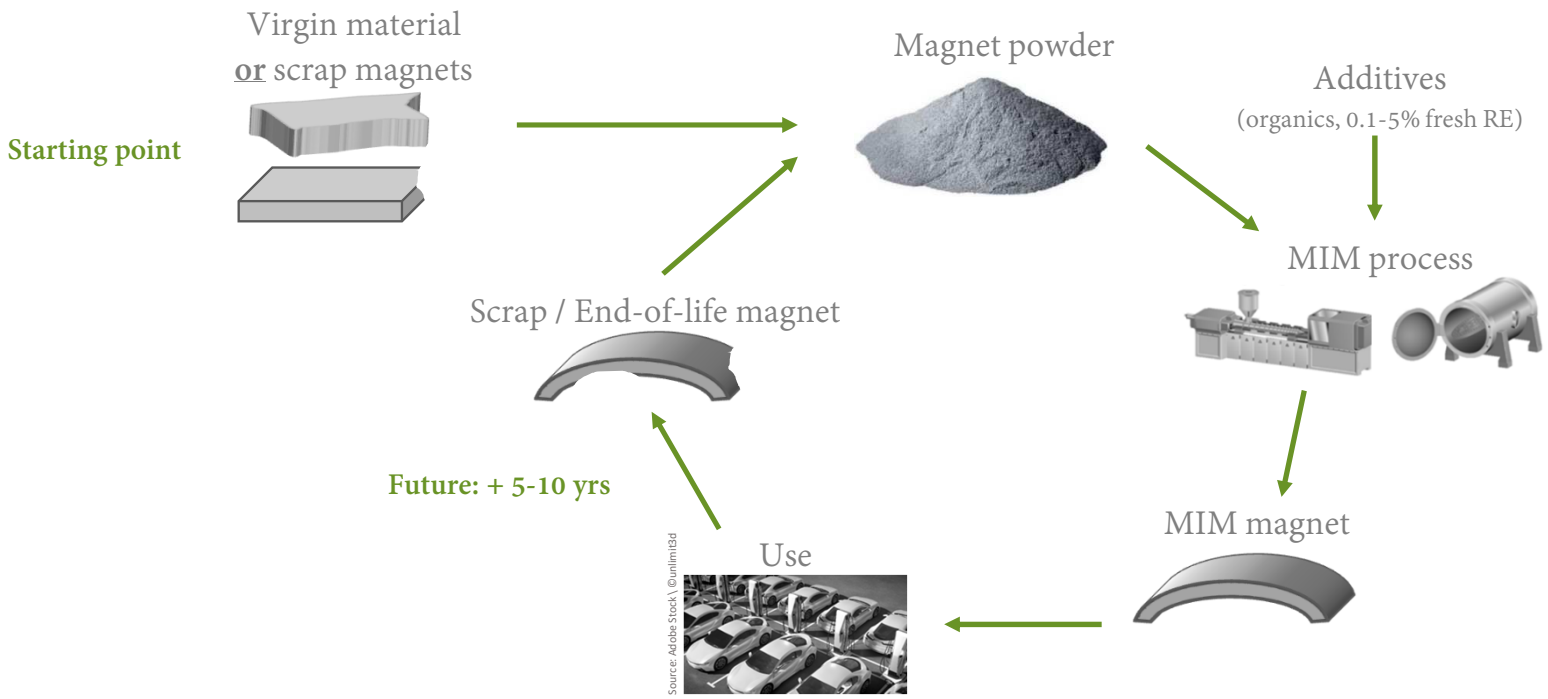
# Closed Loop Magnets Recycling Process in Europe




**MIMplus Technologies has the complete technical capability**

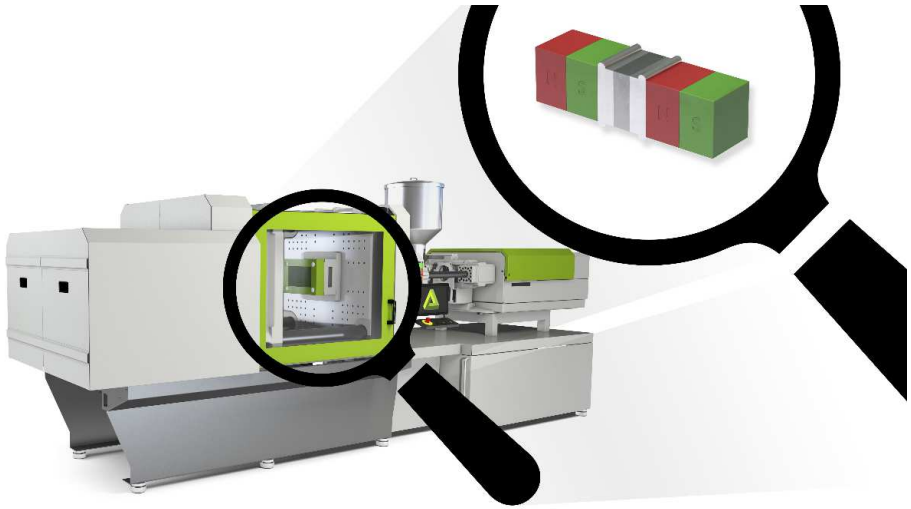
# Metal Injection Molding of NdFeB-Magnets

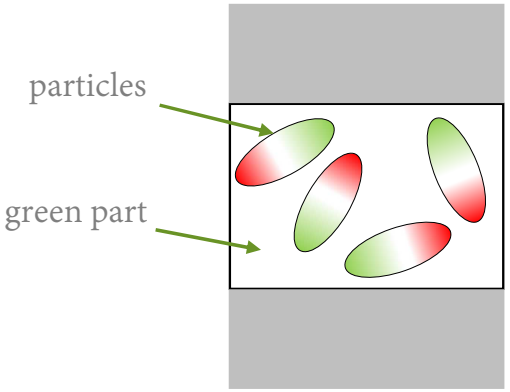
| Virgin material<br>**or**<br>Scrap magnets | Hydrogen decrepitation + Milling | Feedstock production | Injection molding | Debinding | Sintering |
|---|---|---|---|---|---|

In-house at **MIMplus Technologies**

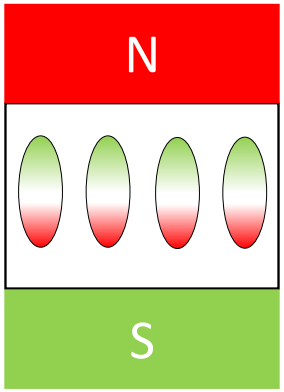
# MIM Part Production – Alignment in Tool

- Special requirement on injection molding tools: internal magnetic field
- Every single powder particle in the feedstock behaves like a single magnet
- Magnetic field in tool allows alignment of particles in the green part






isotropic magnet




anisotropic magnet



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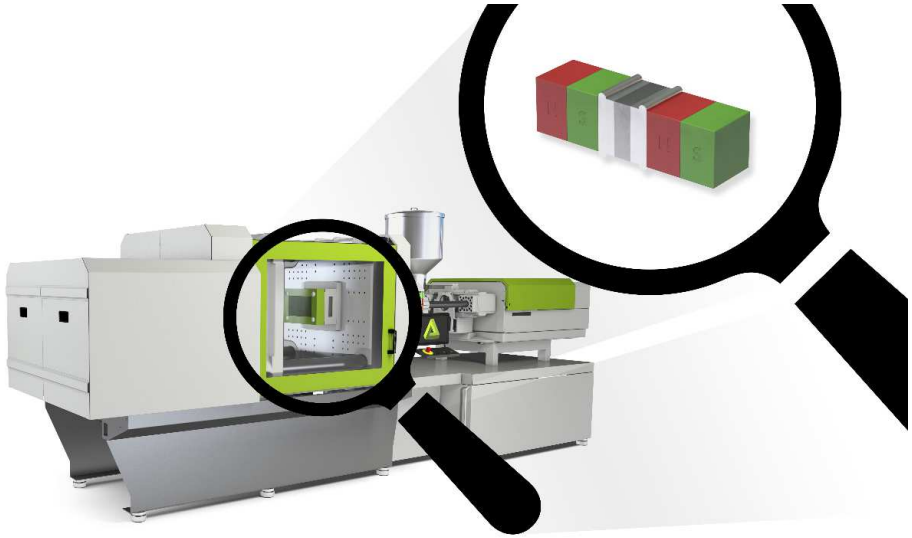
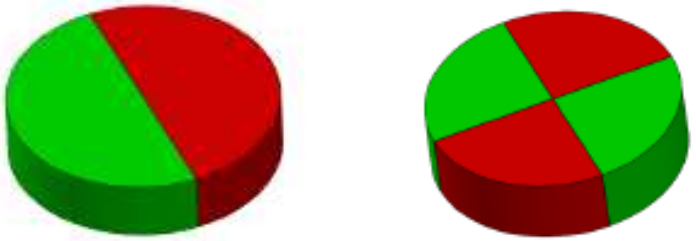
# MIM Part Production – Alignment in Tool

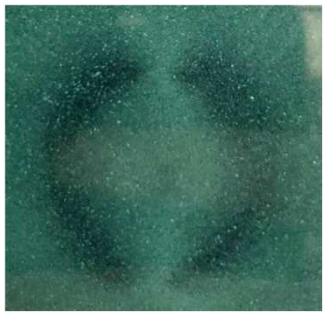
- Complex magnetizations are possible:
  - Multi-pole magnets: e. g. diametrical, radial
  - Halbach arrays





magnetic flux foil

Top view:



Side view:

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SUSMAGPRO has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821114.

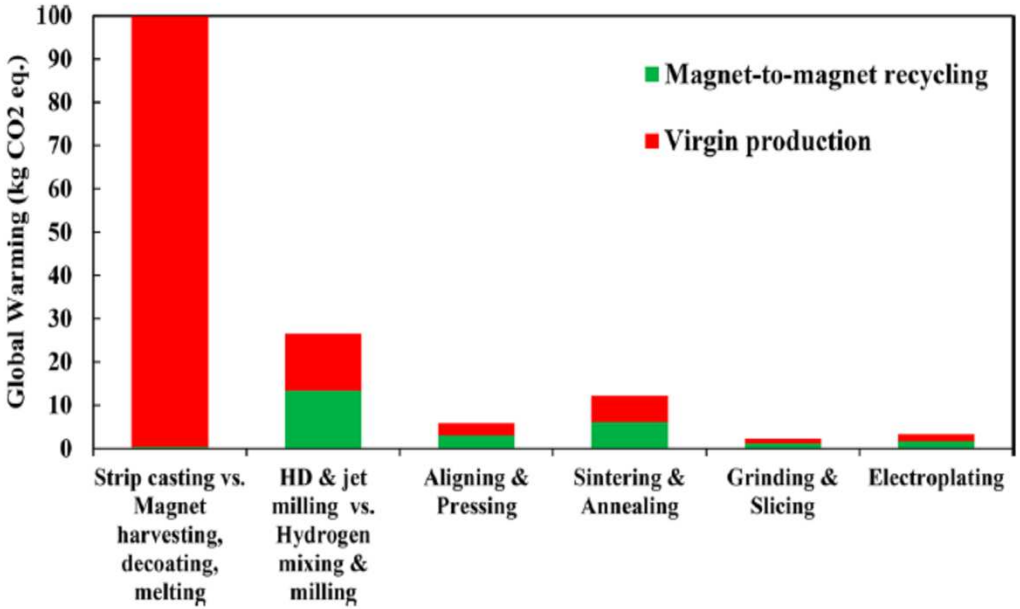
# MIM – An efficient and green production technology

- Metal Injection Molding is a net-shape process:
  - Post-processing is limited to deburring
  - High yield for complex and small magnets
  - No scrap from post-processing like wire cutting etc.

- MIM magnets are in fact sintered magnets
  - Sintered microstructure
  - Properties like sintered magnets

# Global warming potential for press and sintered magnets

**Literature review:** Global warming potential of each processing step in virgin production and magnet-to-magnet recycling for 1 kg of NdFeB magnets via **press and sintering**




| | |
|---|---|
| Recycling: | 25 kg $CO_2$ eq / kg magnet |
| Virgin Production: | 130 kg $CO_2$ eq / kg magnet |

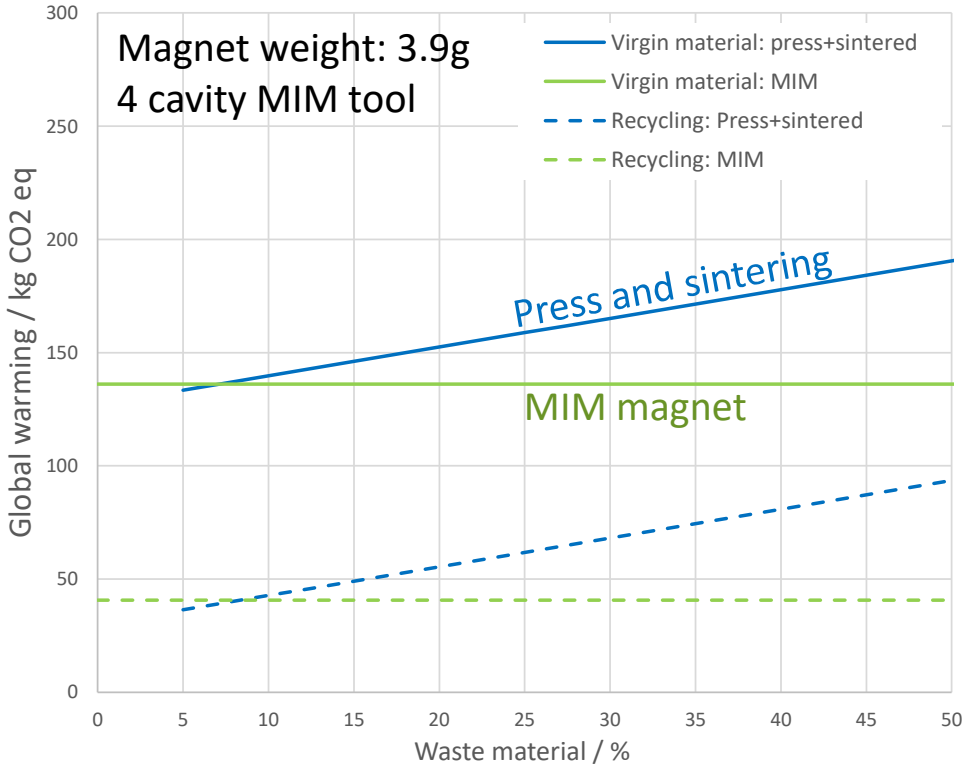
# Material Utilization in MIM process

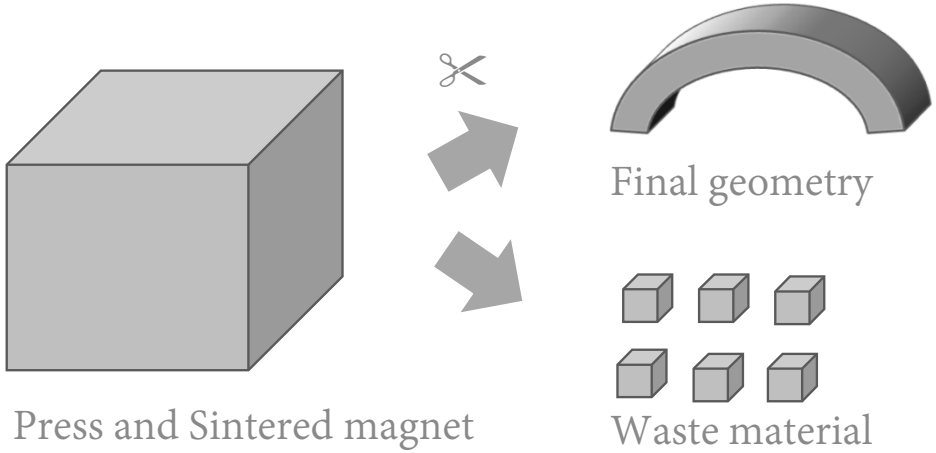
## Calculation uniquely for NdFeB material. Binders are not considered

| Raw material | Processing step | Product | Material utilization | Scrap rate | Comment |
|---|---|---|---|---|---|
| Strip cast flakes | HD | Strip cast flakes, hydrided | 100,0% | 0,0% | Estimation for serial production |
| Strip cast flakes, hydrided | Milling | Powder | 98,0% | 2,0% | Estimation for serial production |
| Powder | Feedstock production | Feedstock | 99,5% | 0,5% | Measured on 5kg batch size.<br>Serial production comparable. |
| Feedstock | Injection molding | Green part | 99,5% | 0,5% | Estimation for serial production |
| Green part | Debinding | Brown part | 100,0% | 0,0% | Measured on 5kg batch size.<br>Serial production comparable. |
| Brown part | Sintering | Sintered part | 96,0% | 4,0% | Estimation. Up to now only smaller batches have been produced. Exact numbers can be determined during fall batch production. |
| | | Overall material utilization for serial parts | 93,0% | | Based on the estimations and boundary conditions mentioned above |

NdFeB Material Utilization in MIM process ≥ 93% .
**Independent on magnet complexity and size!**

# LCA – MIM vs. Pressing




MIM Magnet = Final geometry

**If the press and sintered magnet has more than ~8% waste material it has a higher CO2 eq compared to a MIM magnet. Same trend for recycling material !**

# MIM NdFeB Permanent Magnets

Conclusion:

1. Metal Injection Molding of NdFeB permanent magnets allow highest complexity in geometry and magnetization

2. MIMplus  Technologies can use virgin or recycled raw material

3. The MIM process is a net-shape technology that requires no post-processing of sintered magnets

4. The produced permanent magnets are „*sintered*“ and exhibit comparable magnetic properties to conventionally pressed permanent magnets

5. Global warming potential of MIM magnets for most magnet geometries below that of sintered magnets

***MIM – A green technology***