

REE4EU



Workshop for the Exploitation of the REE4EU technologies – Economic and Environmental assessment

24/04/2019 – Brussels

Colin Jury & Marine Gaillard – Project Managers –

Groupe
INOVERTIS



BIOMASS



WASTE



WATER



ENERGY



NUCLEAR

CONSULTANCY & ENGINEERING FOR INNOVATIVE PROCESSES

CONSULTING

Techno-economic studies,
Feasibility, Solutions benchmarking,
Process optimization

ENGINEERING & CONSTRUCTION

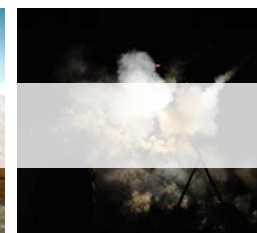
Construction of industrial units,
Chemicals custom production

ENVIRONNEMENT

Decision support tools,
Environmental evaluation,
Process and value chain ecodesign

R&D

Collaborative projects,
Proprietary development,
Trials laboratory, Pilot hub



FOR ALL YOUR ORGANIC WASTE STREAMS

+95%
DCO breakdown

Pressure
100 - 300 bar

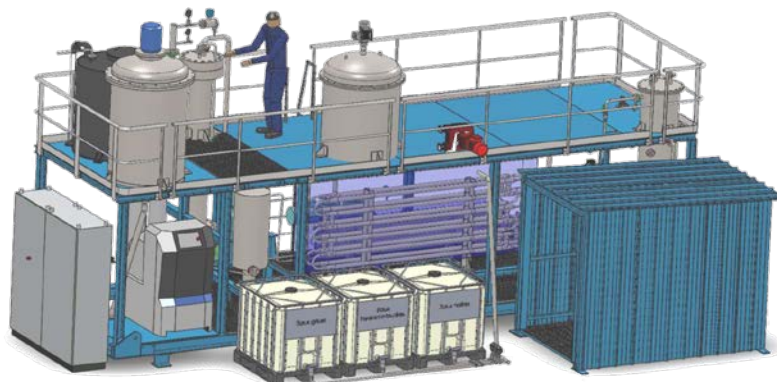
Temperature
200 - 350°C

Capacity
50 - 100 kg/h

COD
up to 150 g/L

Container

OUR **PROPRIETARY** WET OXIDATION PILOT UNIT



OPERATING SINCE MARCH 2019 IN DONZÈRE, FRANCE

> 3



- **Highlights**
- **Environmental analysis**
 - Objectives
 - Why perform an environmental evaluation?
 - What is an environmental evaluation?
 - Results
- **Socio-impact analysis**
 - Overview
- **Economic evaluation**
 - Methodology
 - Economic performance & Viability
 - Economy of scale
 - Investment
- **General conclusions**

- REE4EU is currently an **on-going project**, on a **technology that is still developing**

Current comparison to conventional is not fair

Pilot conditions

- > Current performances
- > To identify the points of optimization



Optimized conditions

- > Improved ILE yield, optimized HTE operating conditions
- > To foresee the potential results and provide a fair comparison

REE4EU BENEFITS



Competitive final cost



Cleaner technology, esp.
Climate Change (kCO₂éq.)



Advantageous facing a
potential Chinese REE cost
increase and security of
supply



Benefit from a **social** point
of view

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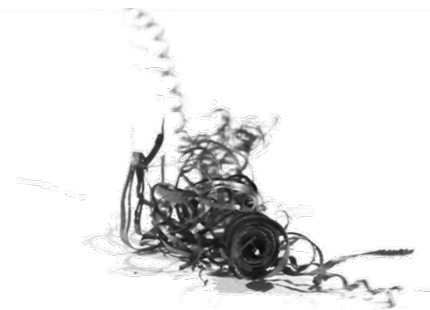
- Compare the **environmental** performances of the production of a Rare Earth Master Alloy (REMA) from conventional mining to its production through REE4EU technologies from different waste streams :

Spent Permanent Magnets SPM



End-Of-Life products

Permanent Magnet Swarf PMS



From PM production

- **It is our duty from a civic point of view**

- Climate change, air pollution to particles, water pollution by nitrate and phosphorus , resources scarcity ...

> *Geologist and scientists stated that we entered in the sixth crisis of mass species extinction*

- **From an investor point of view, it is strategically a good indicator of the safety of an investment:**

- More and more consumers are interested in green products;
- More and more environmental regulations can lower and even ruin the profitability

> *Ex: 1st gen. biofuels & the dieselgate*

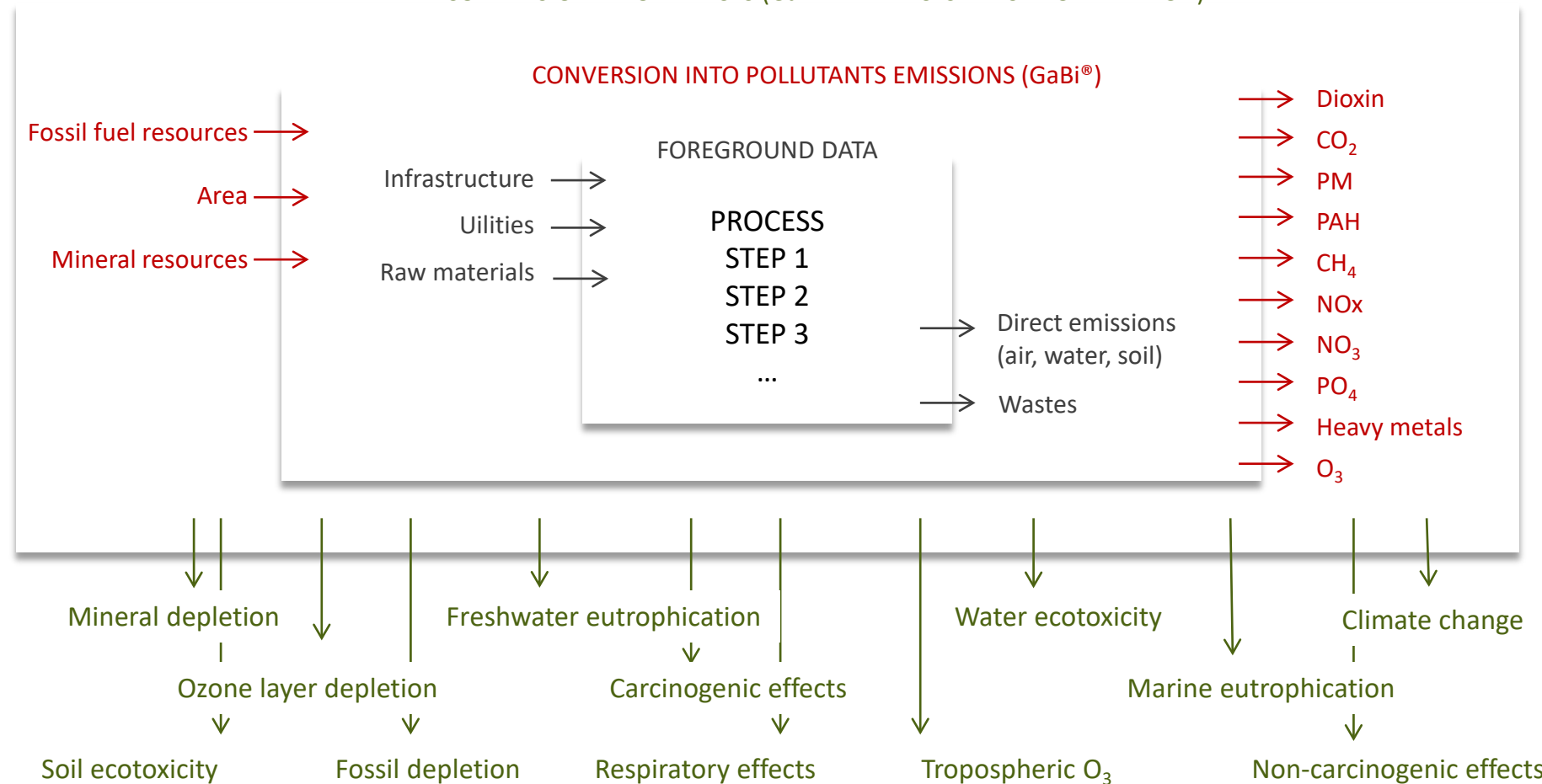
- More and more political and financial support to clean technologies

> Renewable energies, electric vehicles ...

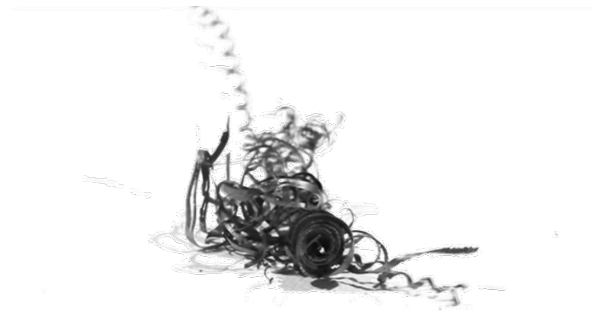
>>> What is an environmental evaluation?

○ Basics on LCA methodology

CONVERSION INTO IMPACTS (GaBi® + IMPACTS VALUATION METHOD)



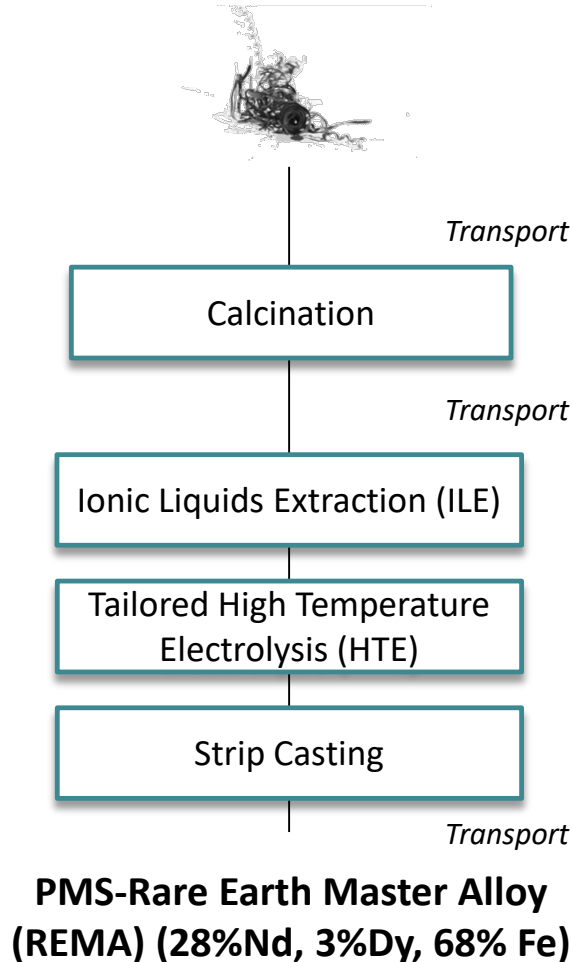
Permanent Magnet Swarf PMS



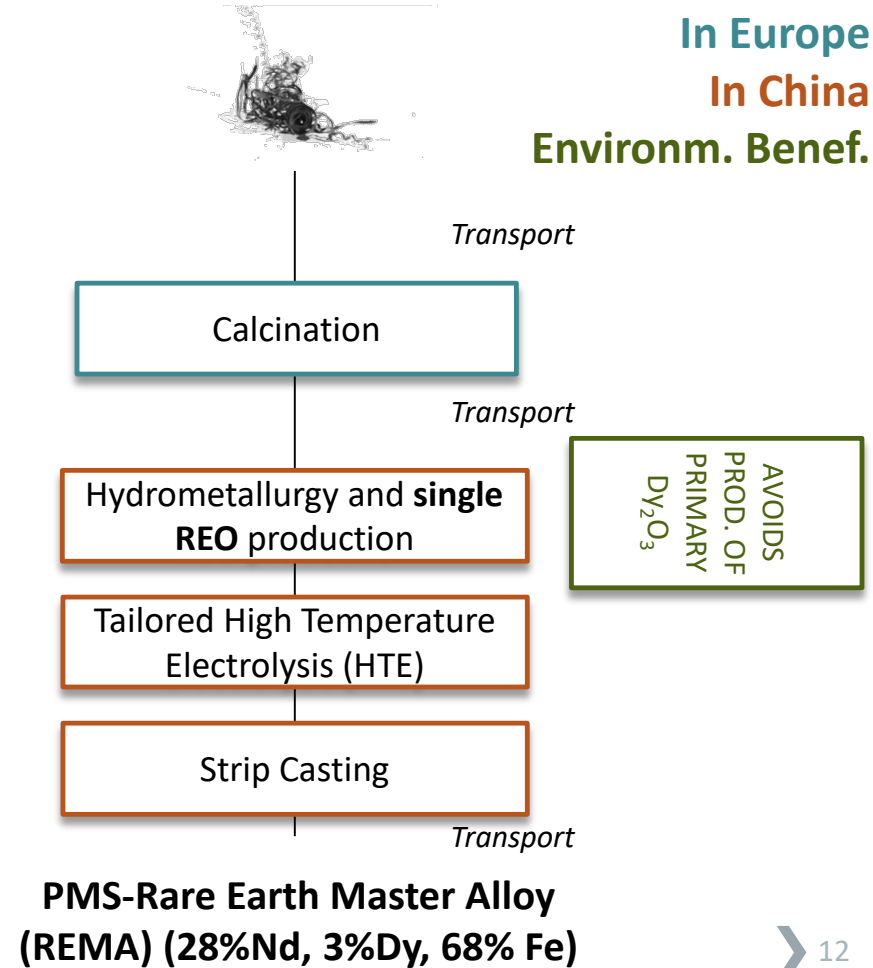
From PM production



REE4EU RECYCLING OF PMS IN EUROPE



CURRENT RECYCLING OF PMS IN CHINA



REE4EU RECYCLING OF PMS IN EUROPE



PMS-Rare Earth Master Alloy (REMA) (28%Nd, 3%Dy, 68% Fe)

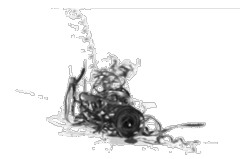
Pilot conditions

30 % recycled RE –
70% Primary RE

Optimized conditions

45 % recycled RE –
55% Primary RE

CURRENT RECYCLING OF PMS IN CHINA



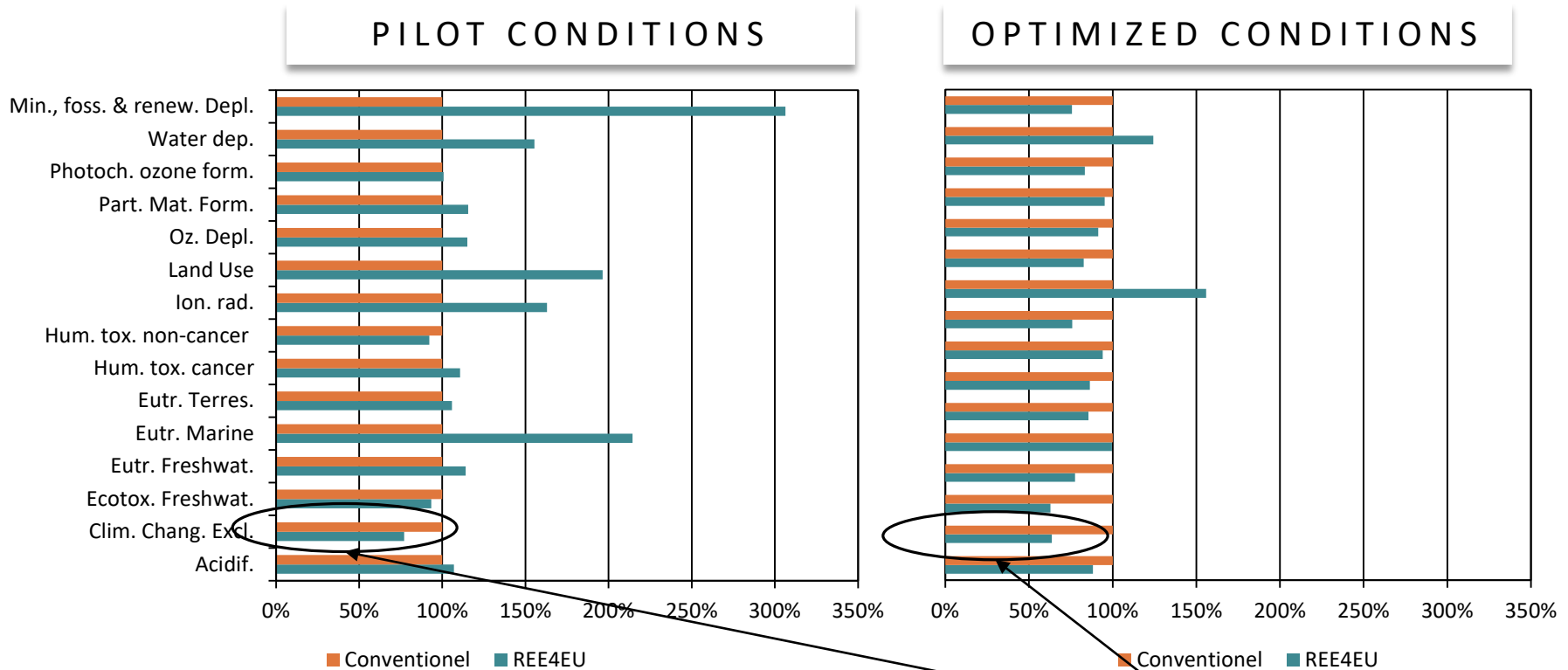
PMS-Rare Earth Master Alloy (REMA) (28%Nd, 3%Dy, 68% Fe)

Conventional

45 % recycled RE –
55% Primary RE



PM Swarf recycling results – Impact categories



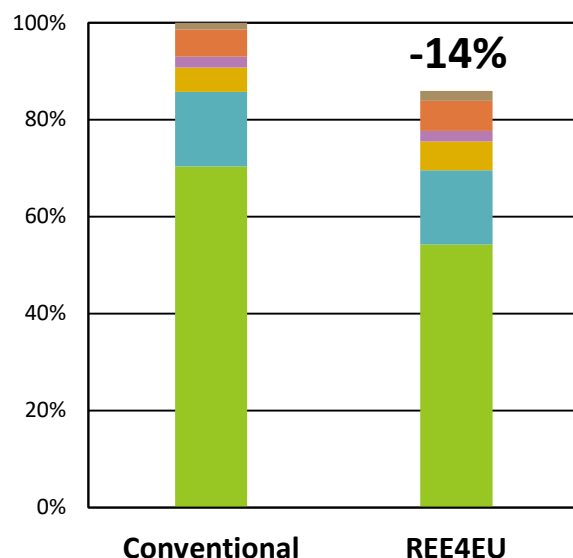
- > Pilot: difference due to
 - Credit of impact
 - Extra fluoride consumption

- > Industrial: Almost all impact categories are equivalent or **to the advantage of the recycling in Europe**

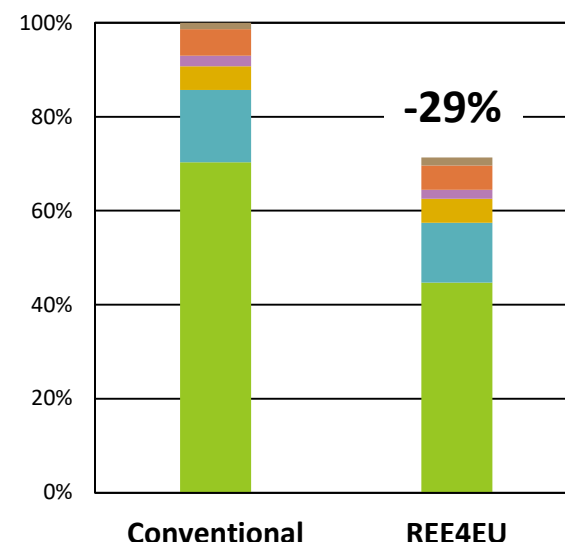
- > **Climate change is always to the advantage of recycling PMS in Europe (- 25 % to 35%)**
because no CF₄ and C₂F₆ emissions during REO electrolysis

- The impacts are aggregated to calculate each scenario' single score

PILOT CONDITIONS



OPTIMIZED CONDITIONS



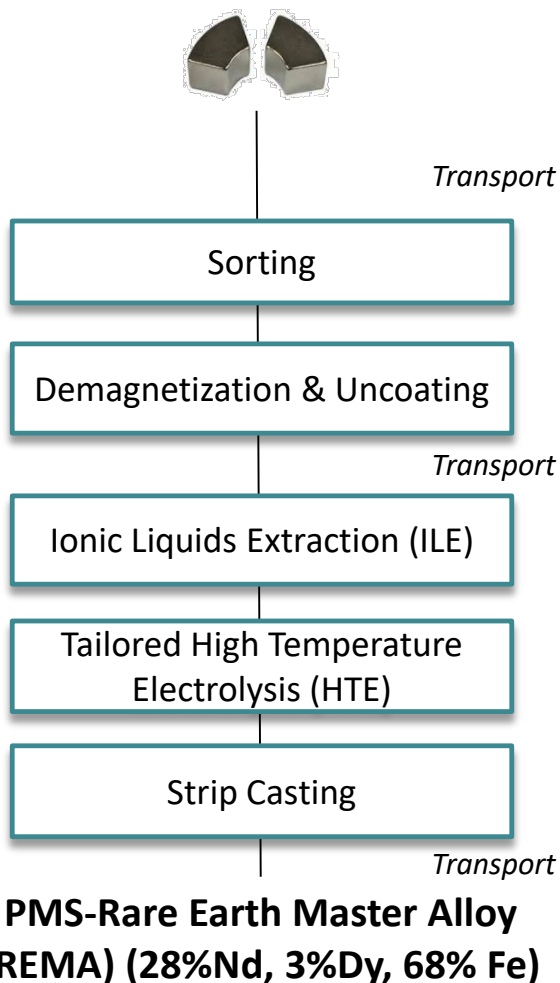
- Single score is always to the advantage of REE4EU - less impact on Climate Change is mainly due to no PFC emissions in REE4EU

Spent Permanent Magnets SPM

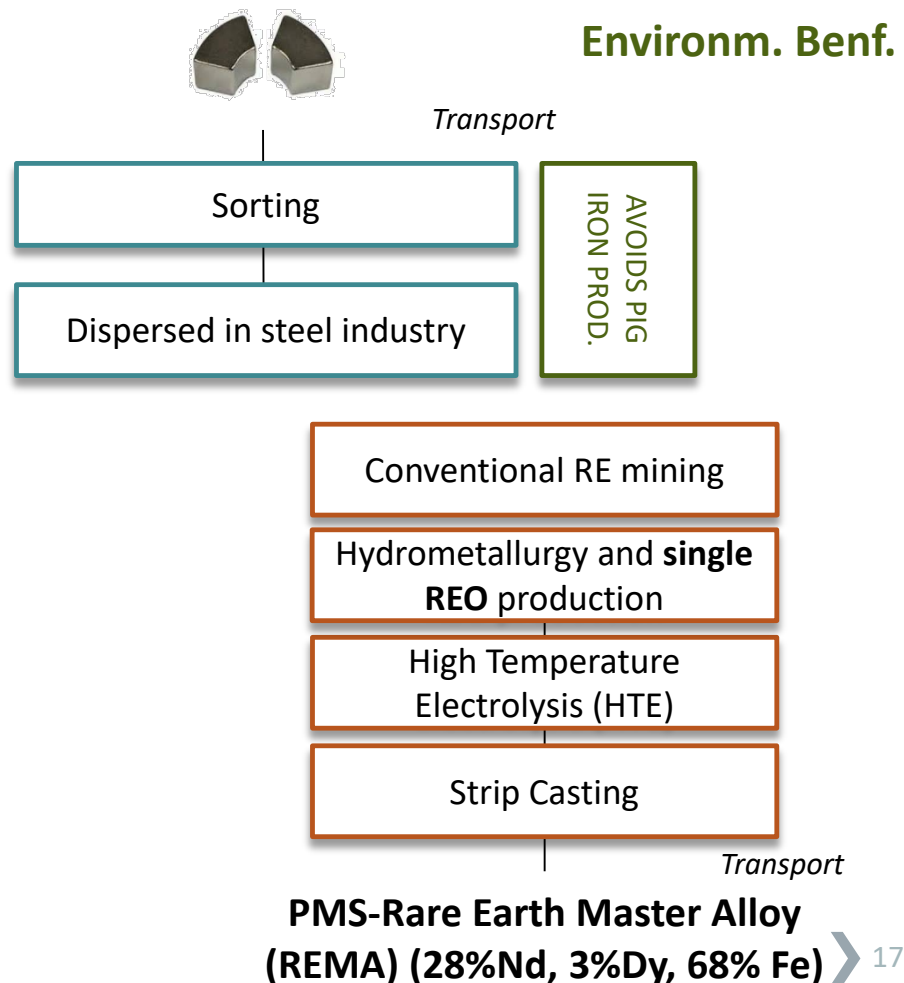


End-Of-Life products

REE4EU SPM RECYCLING & REMA PRODUCTION



CURRENT SPM RECYCLING & REMA PRODUCTION



REE4EU SPM RECYCLING & REMA PRODUCTION



**PMS-Rare Earth Master Alloy
(REMA) (28%Nd, 3%Dy, 68% Fe)**

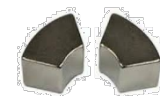
Pilot conditions

30 % recycled RE –
70% Primary RE

Optimized conditions

45 % recycled RE –
55% Primary RE

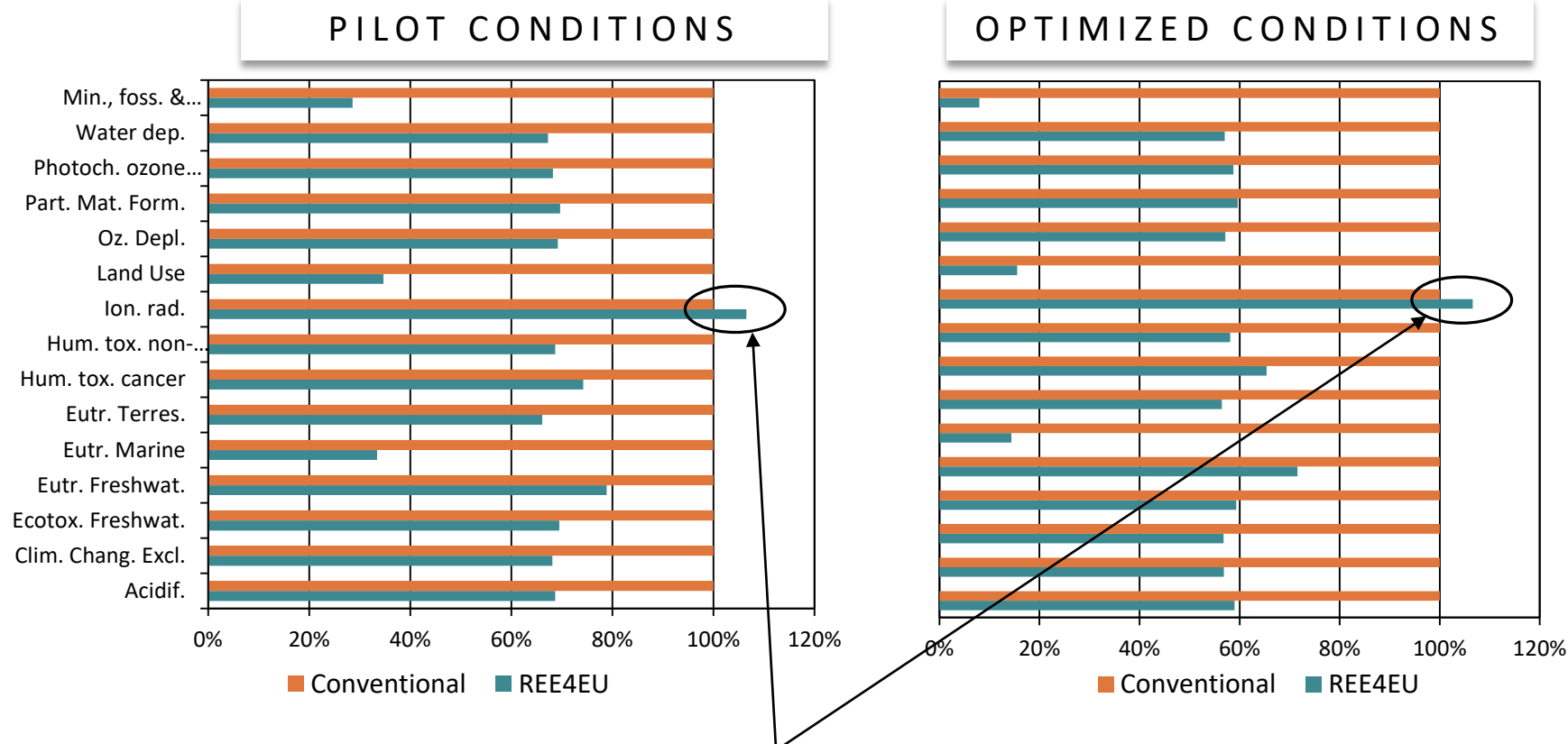
CURRENT SPM RECYCLING & REMA PRODUCTION



**PMS-Rare Earth Master Alloy
(REMA) (28%Nd, 3%Dy, 68% Fe)**

Conventional

100% Primary RE



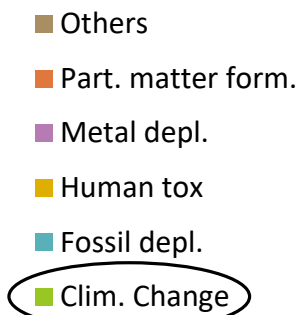
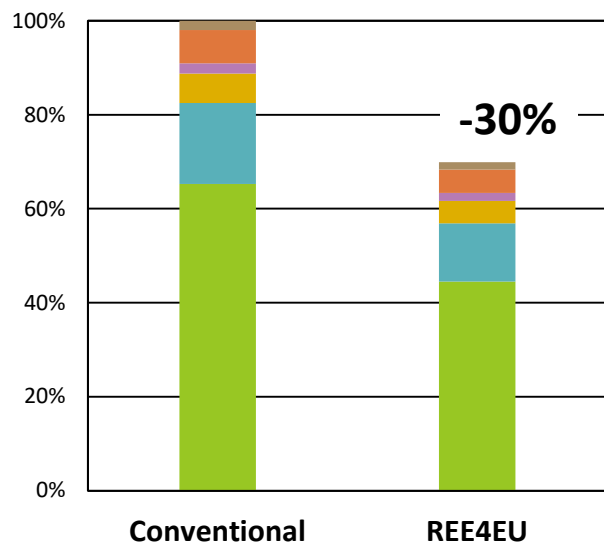
Difference is mainly due to the use of a generic European electricity mix, relying on nuclear power

- > Both Pilot and Industrial projection : difference compared to the conventional scenario is due to greener way of RE production when recycling SPM's RE in Europe

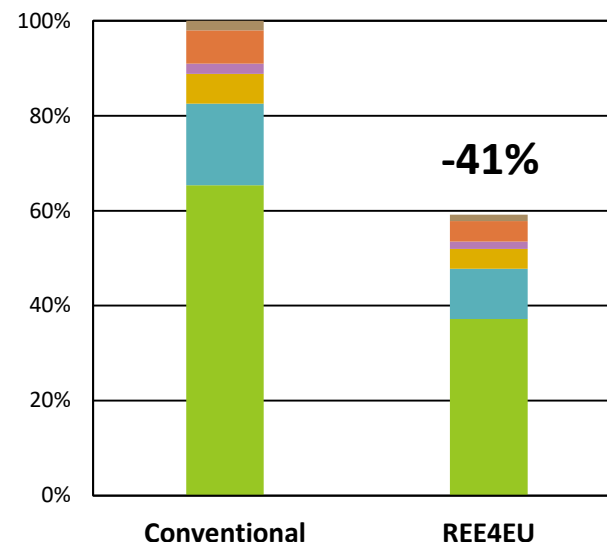
Spent PM recycling results – Single score

- The impacts are aggregated to calculate each scenario' single score

PILOT CONDITIONS

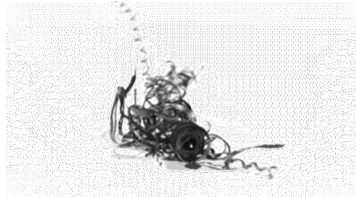


OPTIMIZED CONDITIONS



- Single score is always to the advantage of REE4EU - less impact on Climate Change mainly due to no PFC emissions in REE4EU

Permanent Magnet Swarf PMS



- > Even not fully optimised, the recycling in Europe leads to overall better environmental performances, especially on climate change (-40%) as compared to the conventional scenario

Spent Permanent Magnets SPM



- > Even considering a not finely tuned process (pilot plant), results are better compared to the conventional scenario
- > Reduction of the climate change impact is up to 45%

Besides contributing to the strategic issue of the RE supply in Europe, the implementation of the RE recycling from PMS and SPM through the REE4EU process will help reducing the environmental impact, (especially the climate change impact)

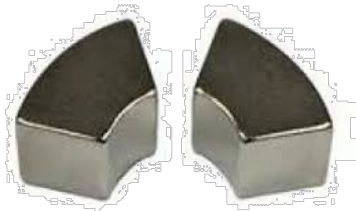
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- Objective: To Compare the **social** performances to produce a Rare Earth Master Alloy (REMA) from conventional mining to its production through REE4EU technologies from different waste streams
- Methodology based on UNEP recommendations :
 - 3 main categories (local communities, value chain actors, workers)
 - ↓
 - 15 sub categories (e.g., local employment, fair competition, fair salary)
 - ↓
 - 30 indicators (e.g., % workforce employed locally, corruption, minimum wages)
 - ↓
- Data source: International Labour Office, World Bank, etc.
- Results similar to the environmental evaluation:
 - PMS – Better considering realistic optimised operating conditions
 - SPM – Better in any case

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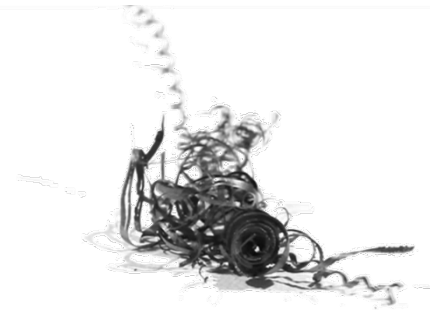
- Compare the **economic** performances to produce a Rare Earth Master Alloy (REMA) from conventional mining to its production through REE4EU technologies from different waste streams :

Spent Permanent Magnets SPM



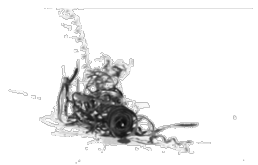
End-Of-Life products

Permanent Magnet Swarf PMS



From PM production

Permanent Magnet Swarf PMS



70 tpa of PMS sludge *

Based on current pilot capacity

Calcination

Ionic Liquids Extraction (ILE)

Tailored High Temperature
Electrolysis (HTE)

Strip Casting

**SPM-Rare Earth Master Alloy
(REMA) (28%Nd, 3%Dy, 68% Fe)**

Spent Permanent Magnets SPM



53 tpa of raw SPM

Sorting, Demagnetization &
Uncoating

Ionic Liquids Extraction (ILE)

Tailored High Temperature
Electrolysis (HTE)

Strip Casting

**PMS-REMA (28%Nd, 3%Dy,
68% Fe)**

Conventional



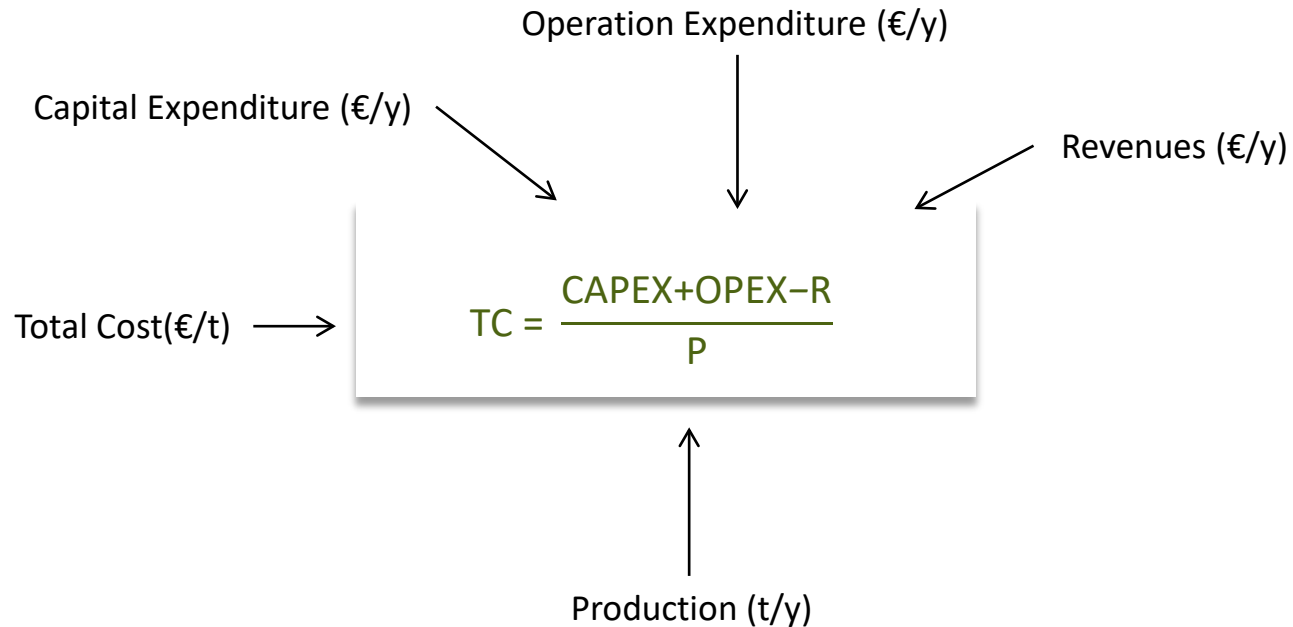
Nd, Pr, Dy, Fe, B from
the Chinese market

Strip Casting

**Conventional REMA
(28%Nd, 3%Dy, 68% Fe)**

*(47 wt% wet content)

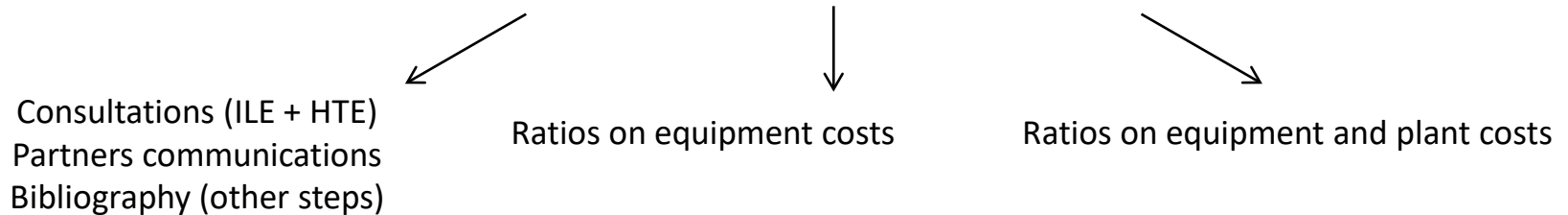
- Final REMA cost estimation



○ CAPEX estimation (10-year-depreciation time)

+/- 30 % estimation

$$\text{CAPEX} = \text{Equipment Costs} + \text{Plant Costs} + \text{Additional Costs}$$



○ Plant costs include :

- Installation
- Instrumentation (extensive)
- Electrical and control device
- Ventilation
- Structure & Piping (solids and liquids)
- Civil Works

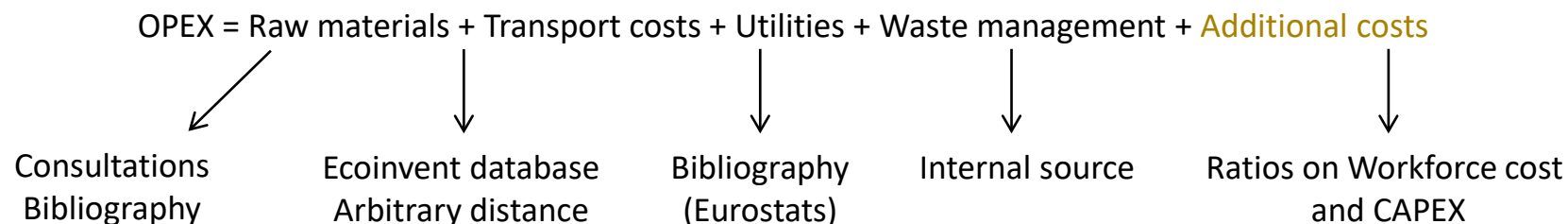
○ Additional costs include :

- Administration
- Project Engineering
- Contingencies

**All costs are actualized to 2018 via inflation recorded in Europe since the reference year*

+/- 30 % estimation

○ OPEX estimation :

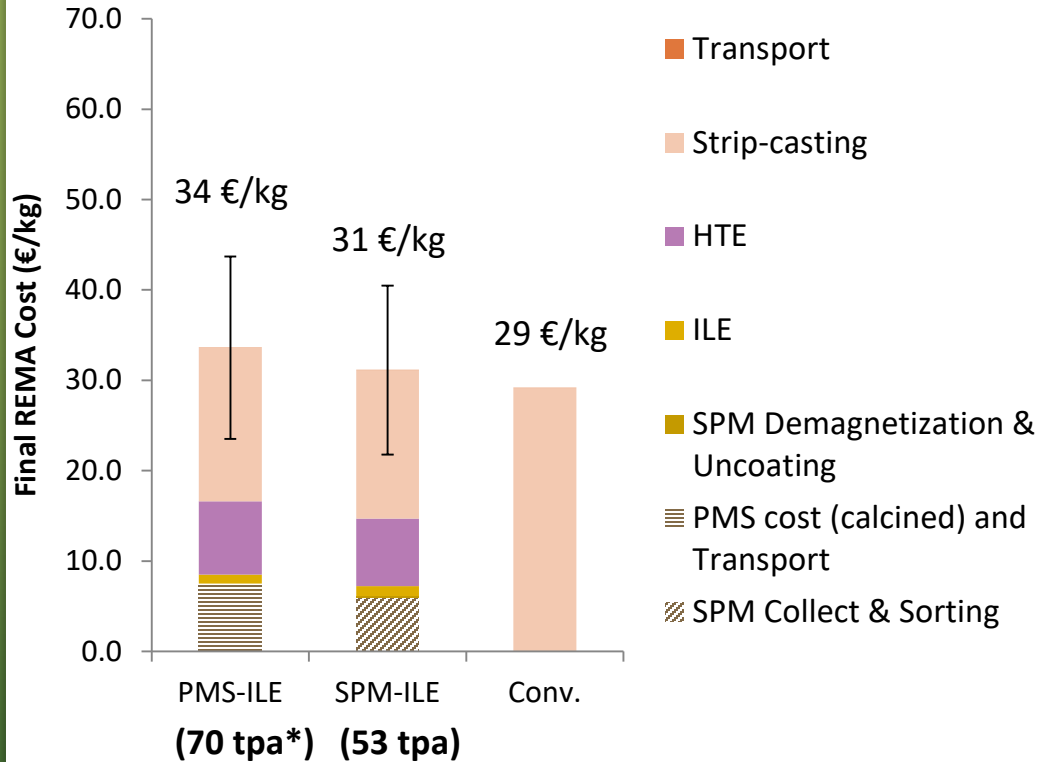


○ Additional costs include :

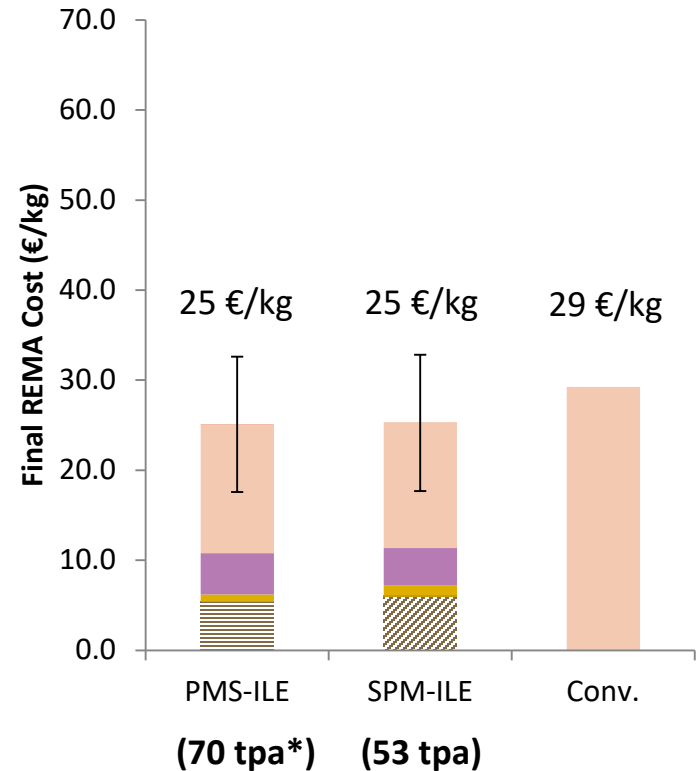
- Workforce
- Maintenance
- Laboratory
- Supervision
- Consumables
- Environmental control
- Local taxes, insurance
- Depreciation
- Environment



PILOT CONDITIONS



OPTIMISED CONDITIONS



○ Final cost is influenced by:

- Sourcing
- HTE
- Strip casting is mainly based on the addition of primary REEs to match the targeted REMA composition

Competitive final cost



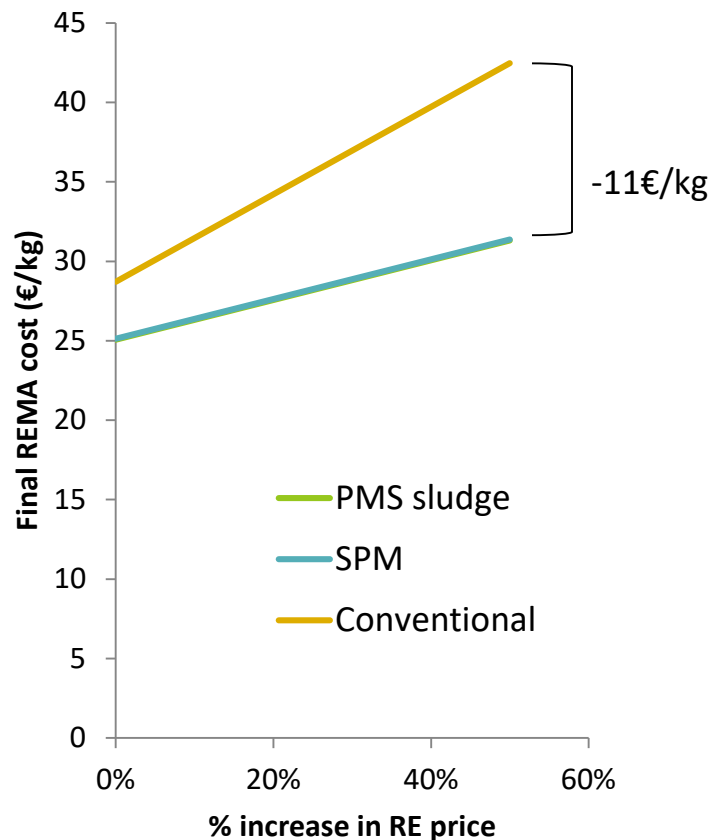
*(47 wt% wet content)



Sustainable Process Industry through
Resource and Energy Efficiency

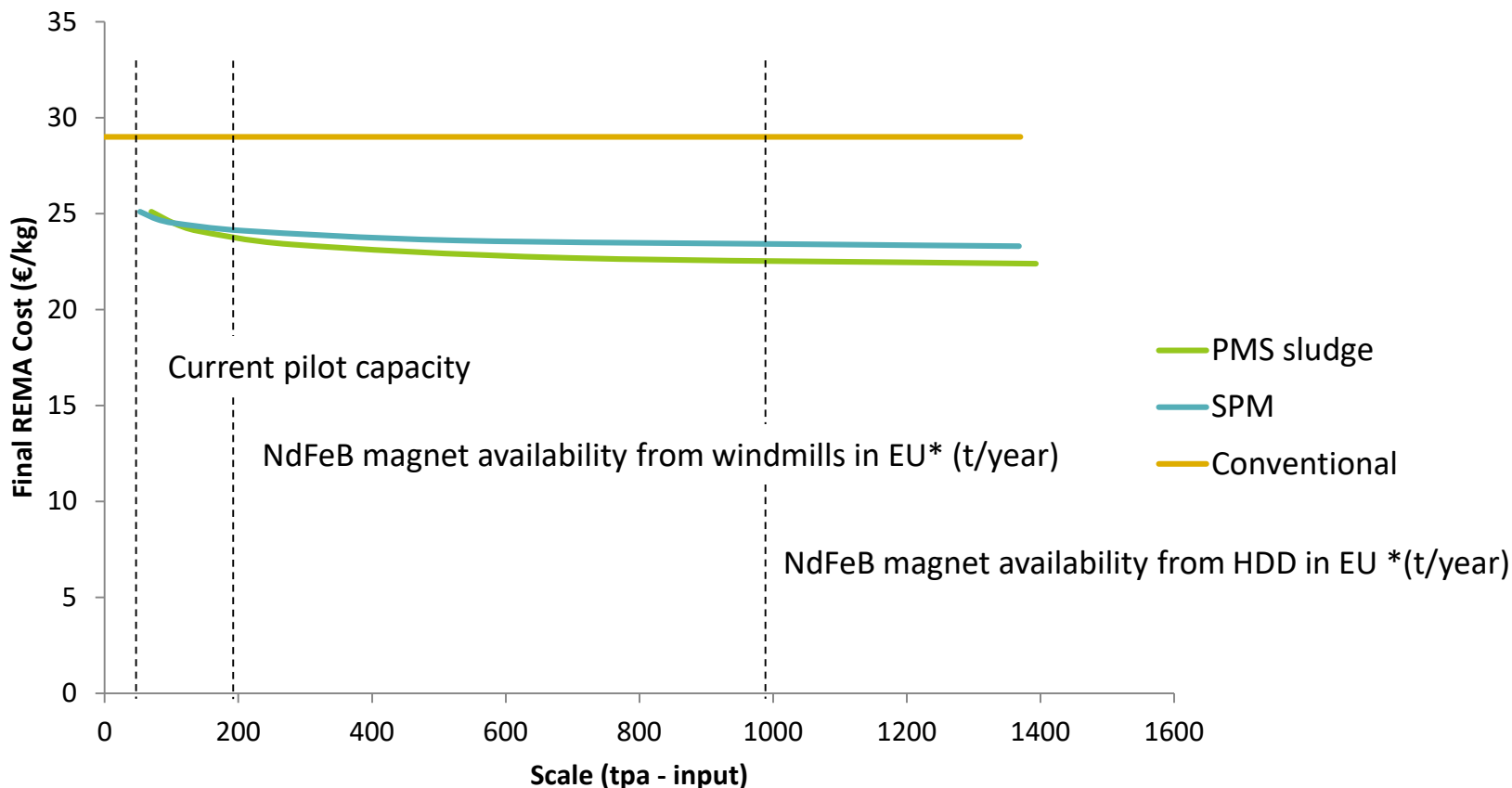


SEMI-INDUSTRIAL CAPACITY:
50 tpa feed



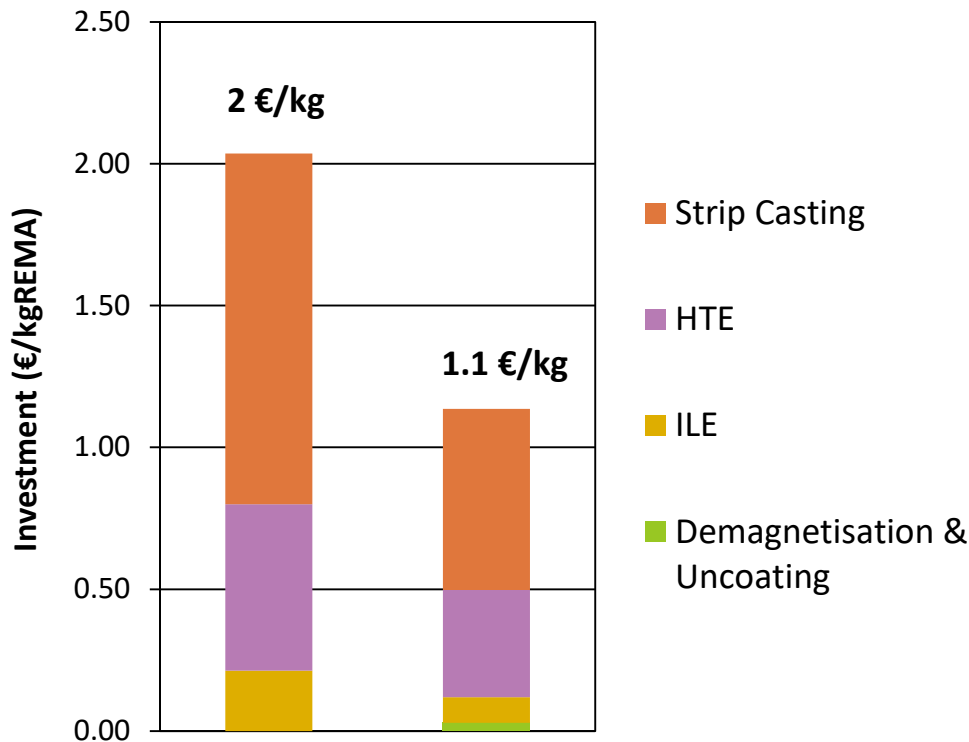
- > Facing an increase in Chinese RE price, REE4EU REMA final cost is less impacted
- > **More secure towards RE price increase**

- Due to the rather OPEX-extensive technologies (ILE, HTE, Strip Casting)
- **CAPEX is between 2% and 6% of final REMA cost**

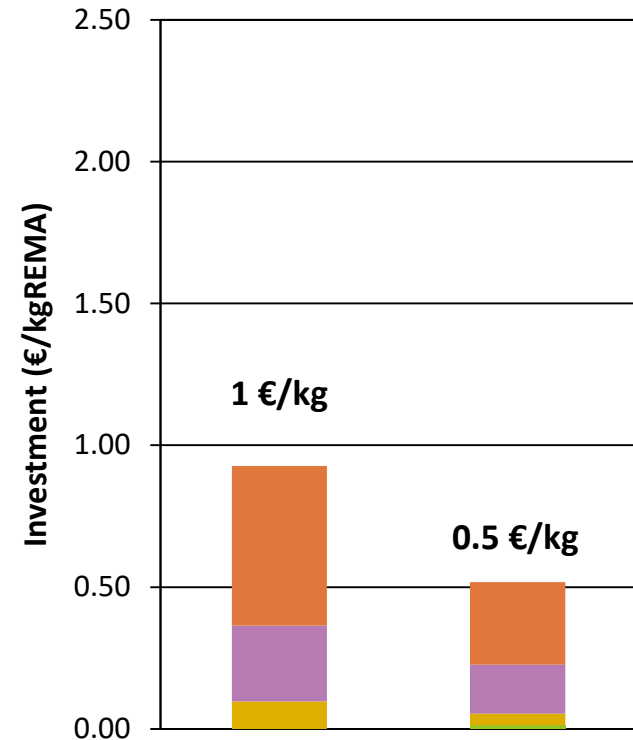


*PNO market analysis report – 2 000 t from windmills by 2030.

SEMI-INDUSTRIAL CAPACITY: 70 tpa feed

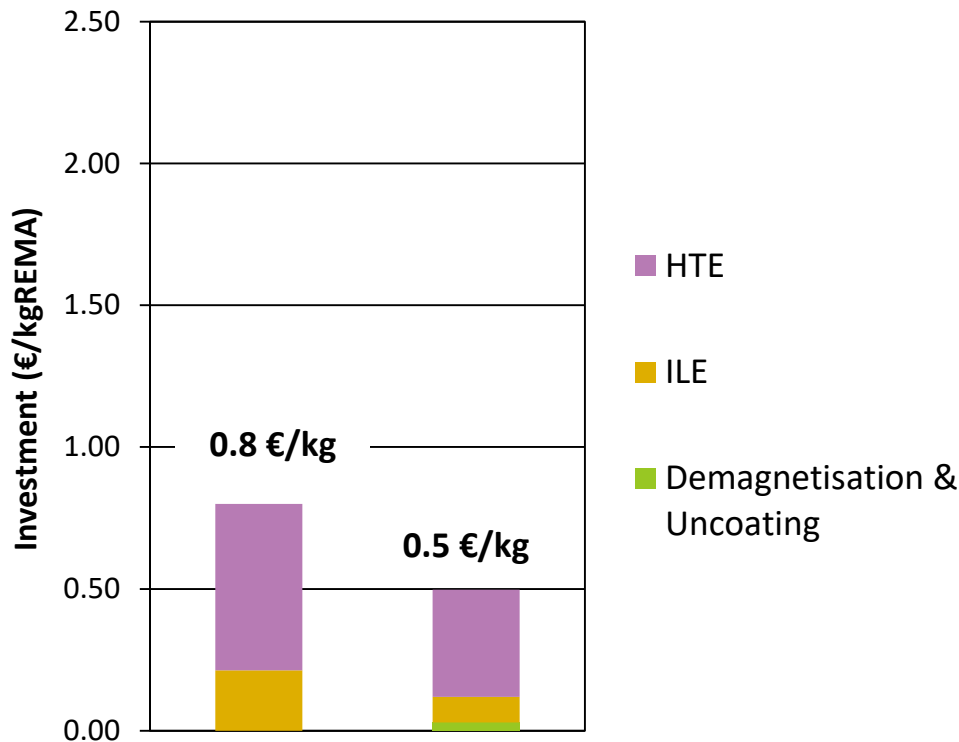


INDUSTRIAL CAPACITY: 500 tpa feed

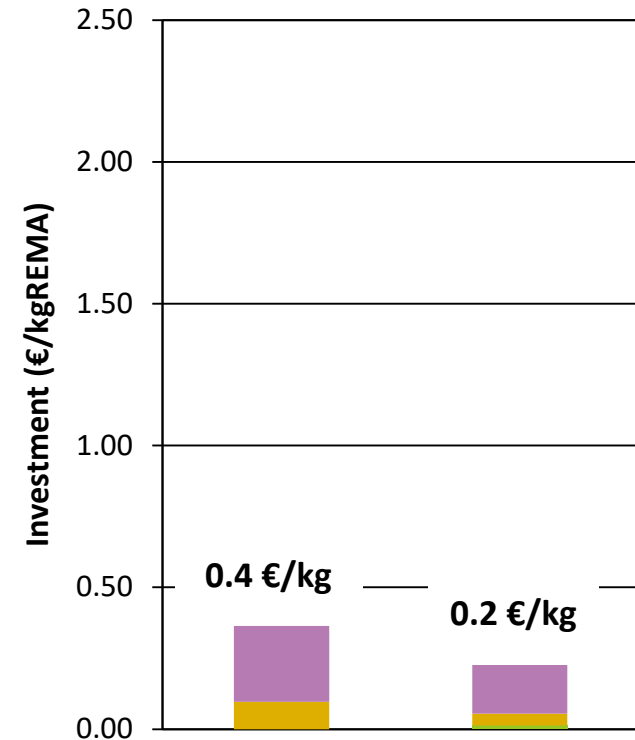


- > CAPEX of the strip casting is based on commercial document of BHP steel and is adapted according to the plant capacity

SEMI-INDUSTRIAL CAPACITY: 70 tpa feed



INDUSTRIAL CAPACITY: 500 tpa feed



- > CAPEX of the strip casting is based on commercial document of BHP steel and is adapted according to the plant capacity
- > - 50 % investment if strip casting is subcontracted (to LCM for instance)

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Pilot conditions

- > very promising socio-economic and environmental results
- > enlightens key points to improve the whole value chain

Realistic industrial projection

- > competitive economic results (REMA final cost)
- > undeniable socio and environmental benefits ;

Facing a potential Chinese RE cost increase, the economic added-value is clearly-evident and the findings of REE4EU reveal that the technology will be very strategic for the European industry



Thank you for your attention