Low Carbon Furnace

Different ways towards the future of ironmaking with ammonia and HBI

Peter Kinzel | Fernand Didelon

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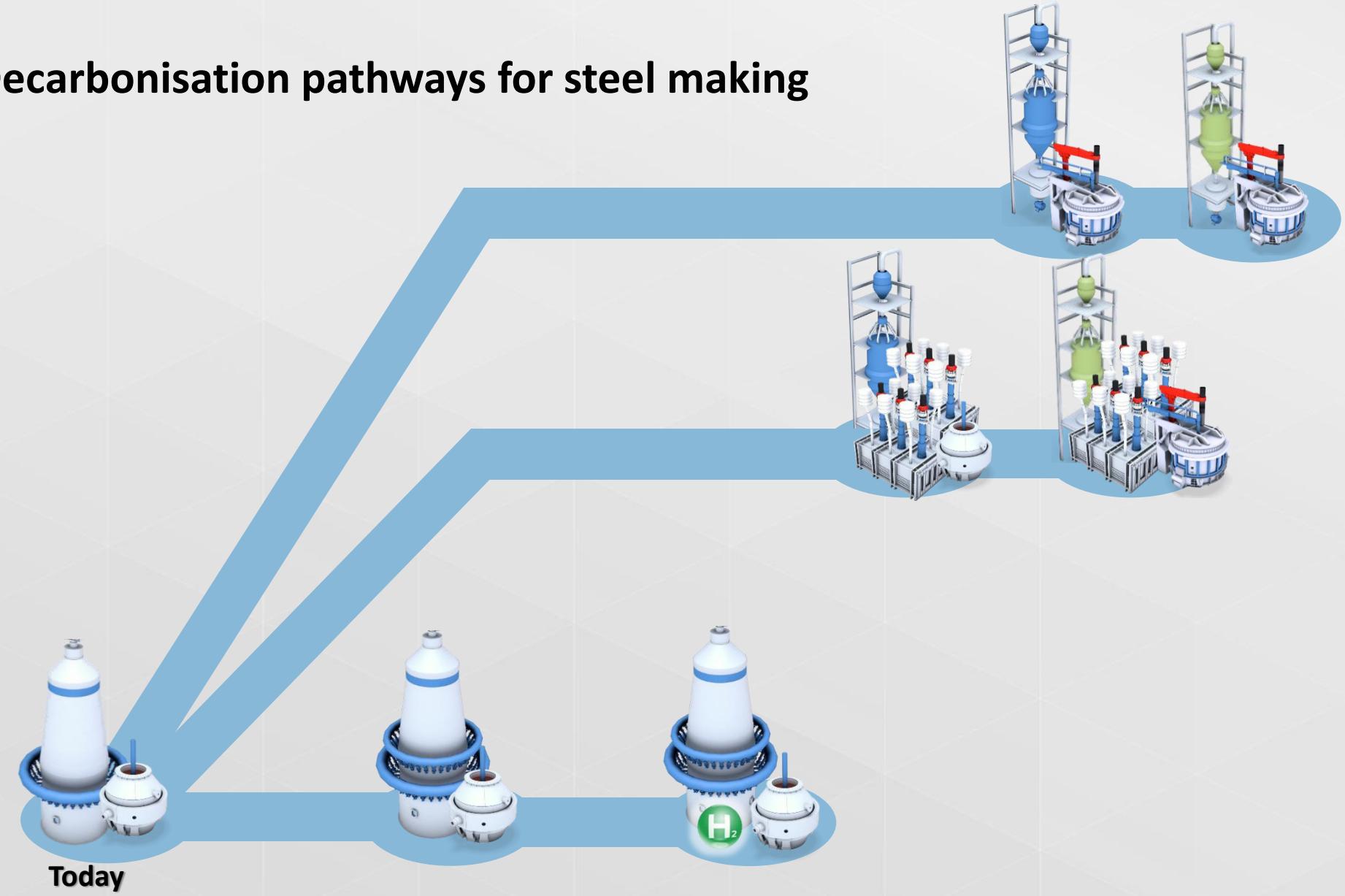
Decarbonisation pathways for steel making



DRI-EAF route

Direct reduction into
electric arc furnace

DRI-OBF route

Direct reduction into
open bath furnace into
basic oxygen/electric arc furnace

Blue BF route

Blast furnace into
basic oxygen furnace

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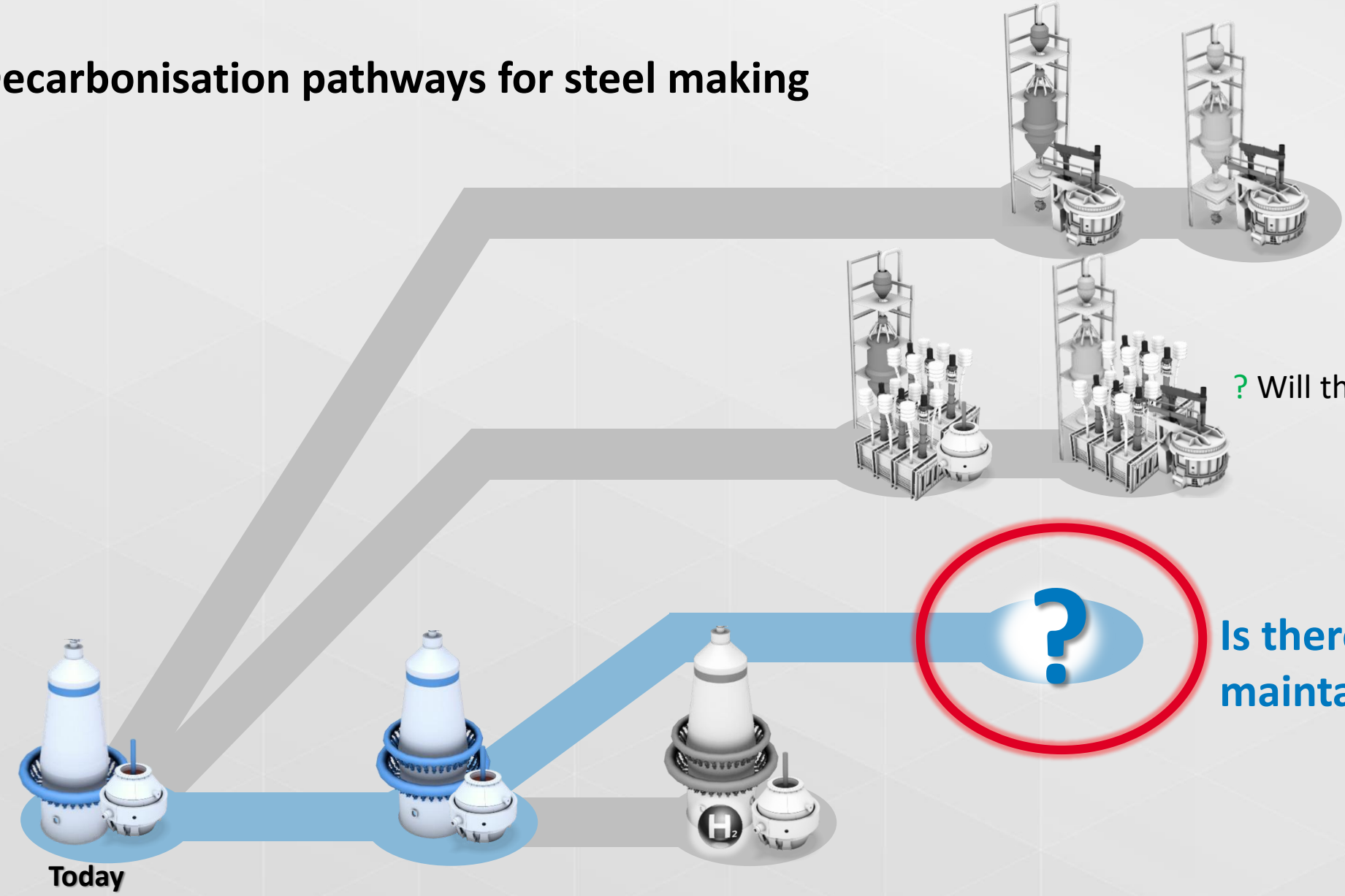
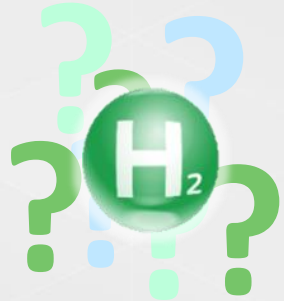
Decarbonisation pathways for steel making





? Will there be enough cheap green H_2?

Is there another way to maintain existing facilities?

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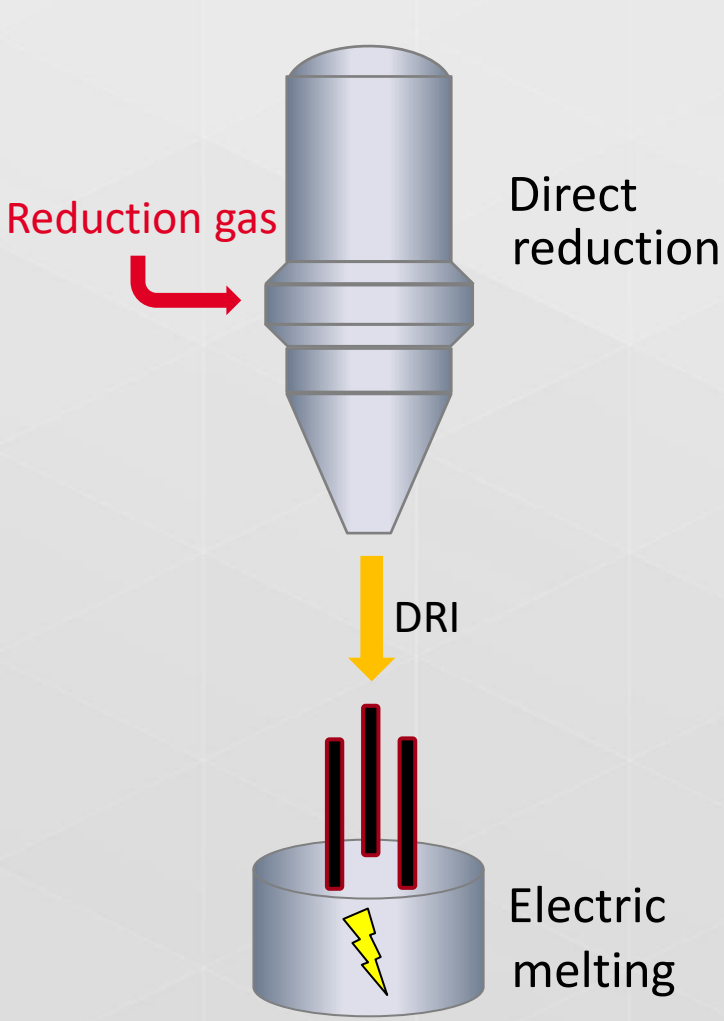
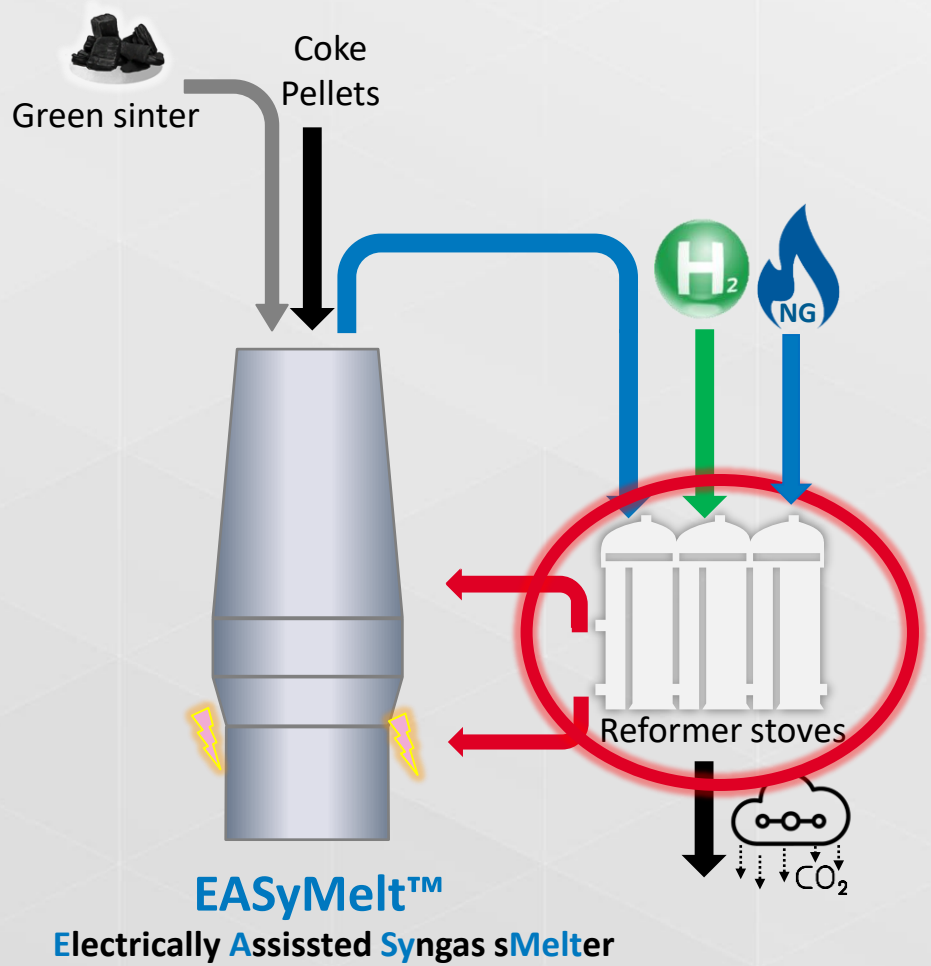
Patent pending

Alternative net-zero CO_2 direct reduction concept





EASyMelt™
Electrically Assissted Syngas sMelter

EASyMelt™ features

- **Net-zero carbon**
- **Lowest OPEX**
- **Lowest CAPEX**
  - Integrated into existing steelshop
  - Stepwise **low risk** approach
- **Energy & ore flexibility**
- **Waste recycling in sinter possible**
- **High production rate & quality**

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Patent pending

Syngas dry reforming pilot plant

- **Successful pilot plant** testing using **BFG** and **COG**

  Dry reforming **without catalyst**

  $CO_2 + CH_4 \rightarrow 2\,CO + 2\,H_2$

- Very high conversion X_{CH4} **> 98%**
- Very **high syngas quality** obtained

	Input	Output
CH_4	10%	0.2%
$\frac{H_2 + CO}{H_2O + CO_2}$	3.9	48

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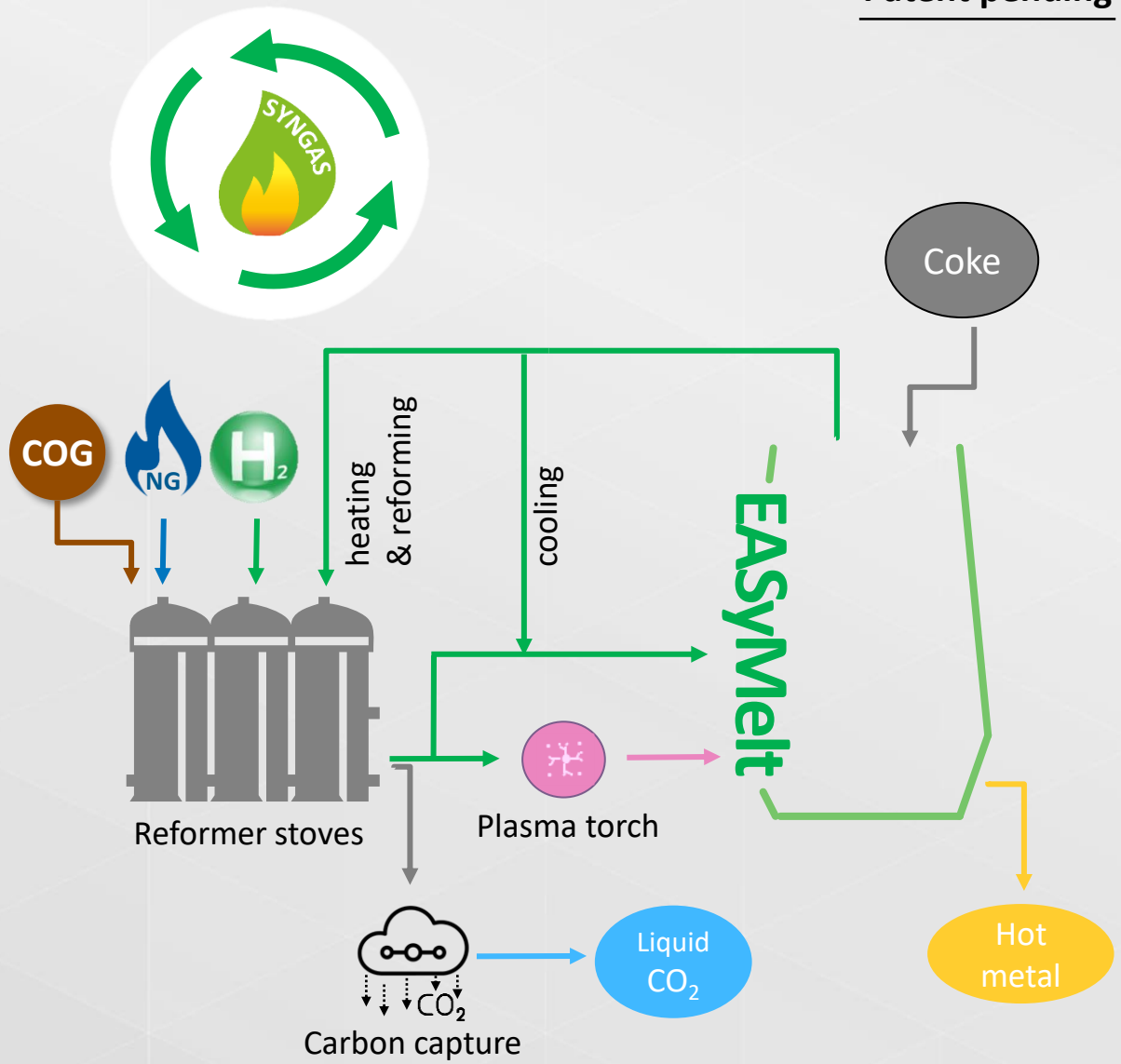
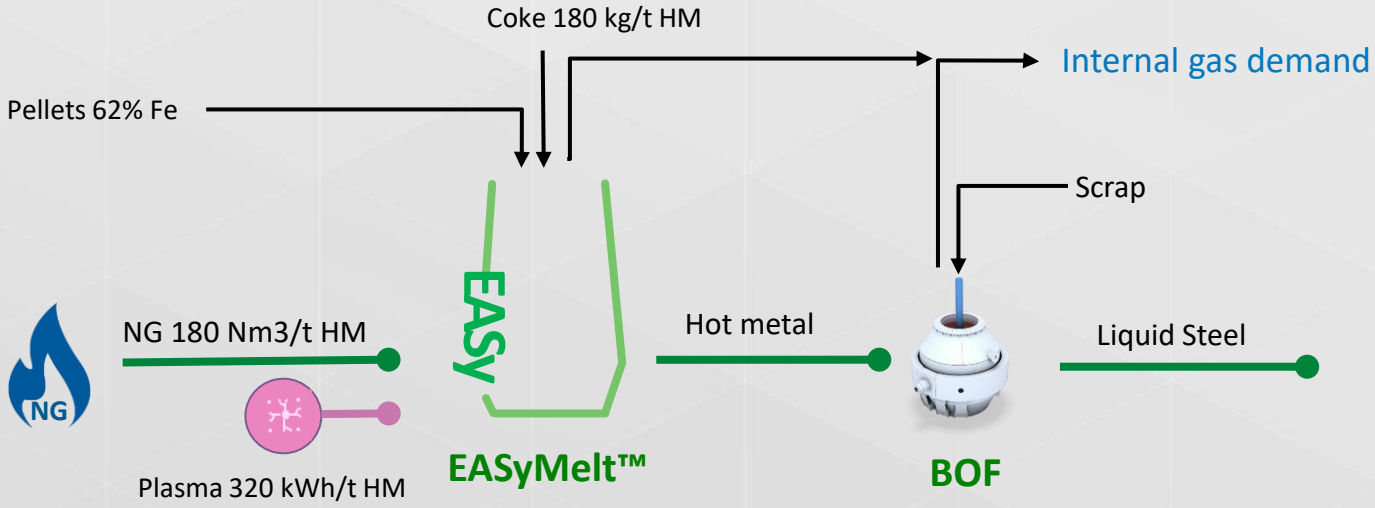
Technical concept of EASyMelt™

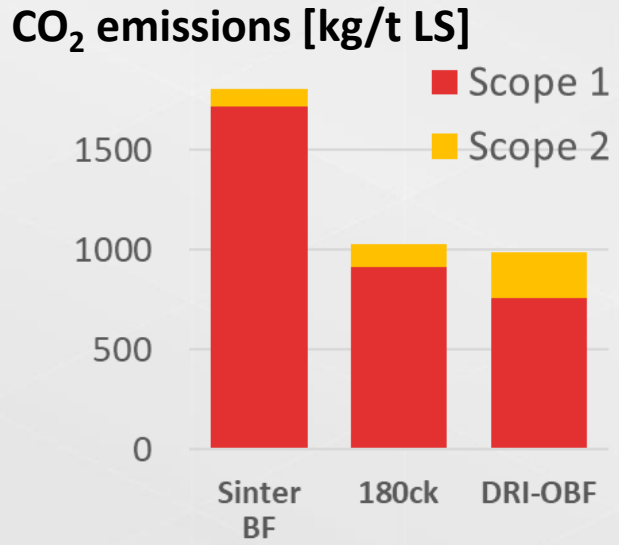
- **No blast**, little consumption of cold oxygen
- **No PCI,** nor auxiliary fuel injection
- Novel **reducing gas technology**
  - Top gas will be **recycled** for syngas production with NG and/or COG and/or H_2
  - Syngas injected at lower shaft **and** tuyere level
  - Tuyere syngas **superheated** to ~2000°C by **plasma torch**
- For **Net zero CO2 solution**, highly cost efficient **CCUS** possibility

→ Coke rate of **100-180 kg/t HM** possible



EASyMelt low carbon furnace 180 kg coke rate without H_2





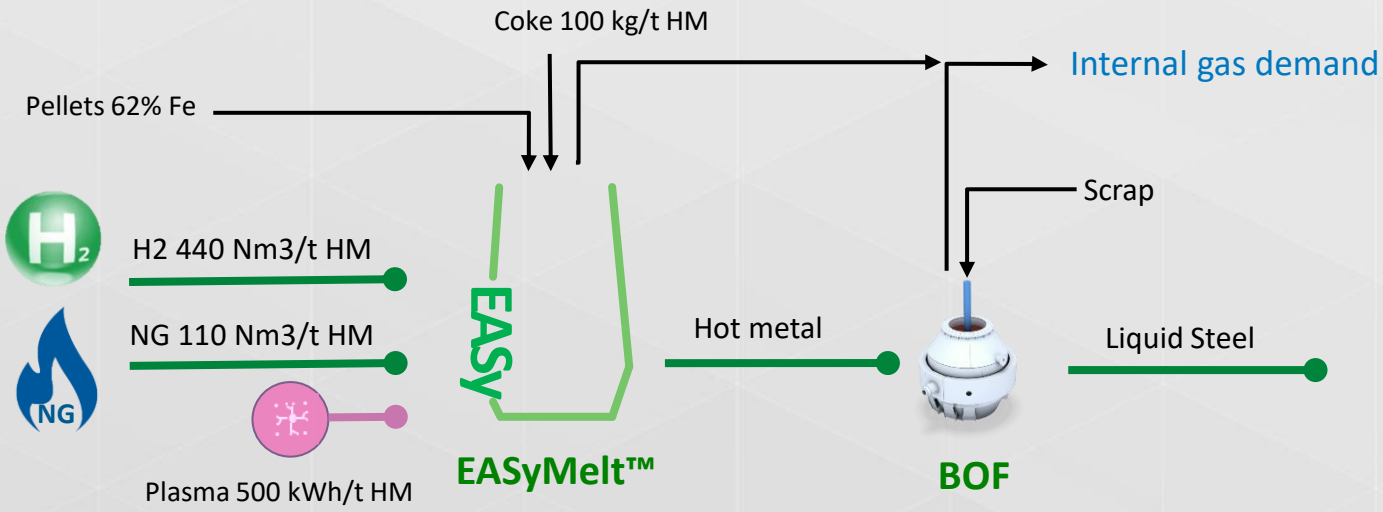
OECD EU-28, emission factor of 300kg/MWh (target 2030)

› **Only 43kg CO_2 more than NG-DRI/OBF route**

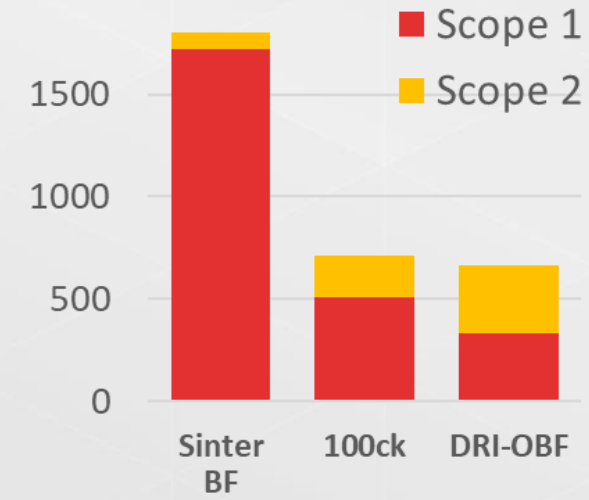
CO_2
1028 kg/t LS
-43%

Patent pending

EASyMelt low carbon furnace 100 kg coke rate with H_2



CO_2 emissions [kg/t LS]



OECD EU-28, emission factor of 300kg/MWh (target 2030)

› **Only 47 kg more or 2,5% less reduction in CO_2 than H2-DRI/OBF route**

CO_2
711 kg/t LS
-61%

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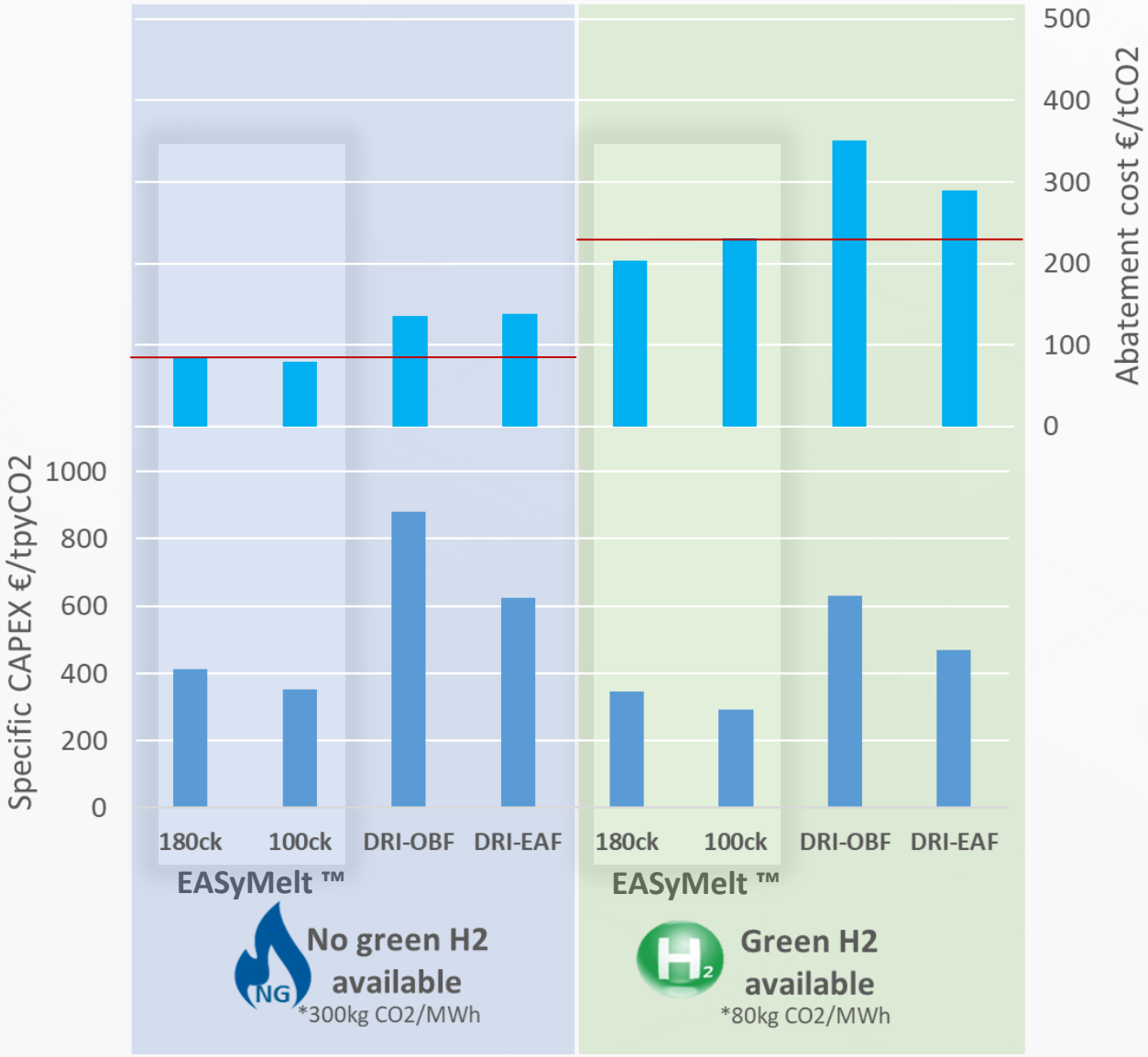
Patent pending

CO_2 abatement cost efficiency



Prices used for OPEX calculation

CO2 emission electricity*	kg/MWh	300 / 80
LV coking coal FOB AUS	$/t	300
Electricity	€/MWh €/GJ	100 28
Hydrogen	€/GJ	50
Natural gas	€/GJ	12
BF pellets premium	$/t	75
DR pellets premium	$/t	100
Scraps	€/t	450

- By far lowest CO_2 abatement cost
- EASyMelt™ roughly **half the CAPEX than DRI-OBF alternative**
- Overall **best financial** option!

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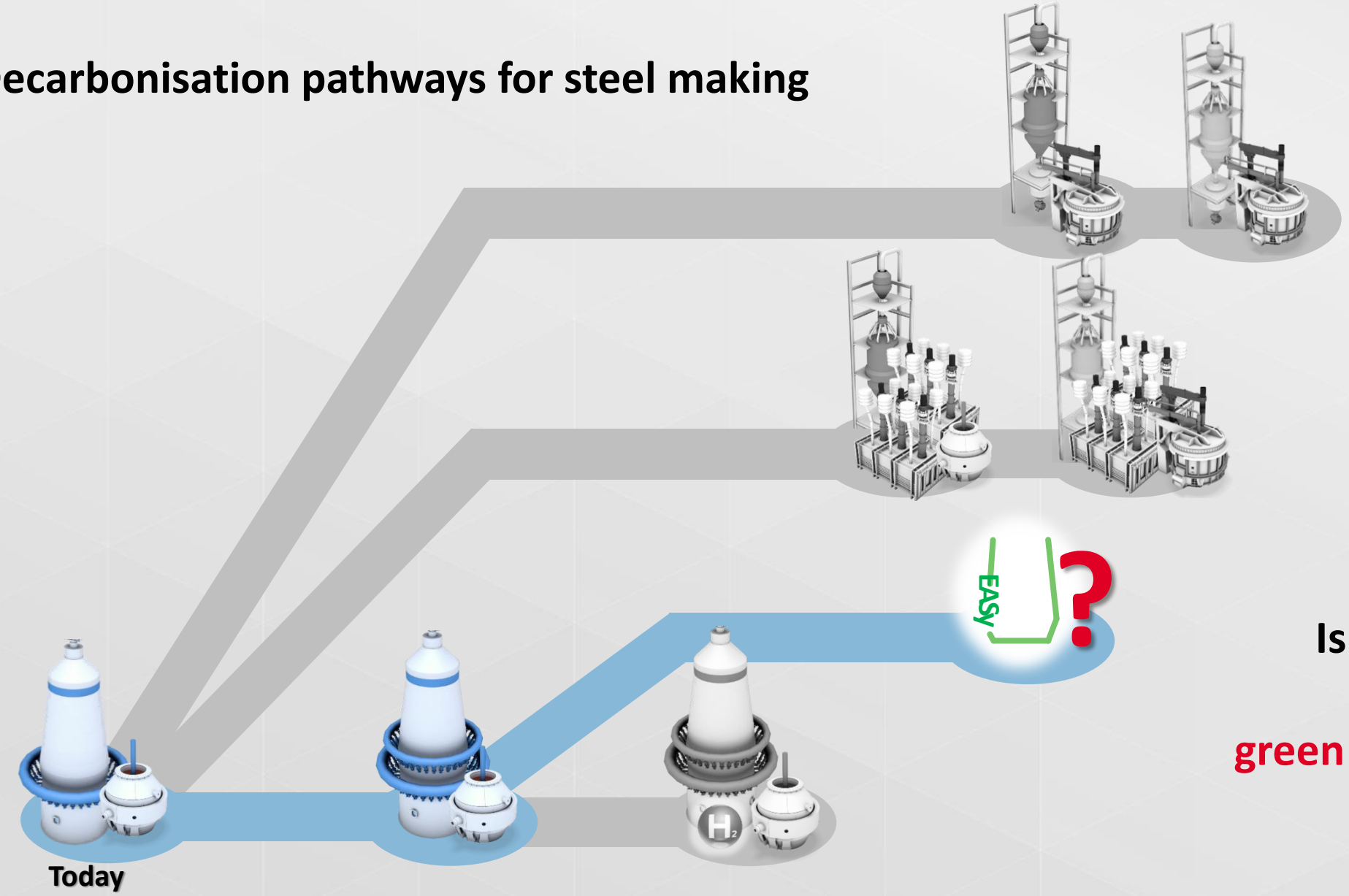
Decarbonisation pathways for steel making



Is there a solution without local green electricity, H_2 & NG?

100% 75% 50% 25% Net-zero

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H_2 for ironmaking – a key in short supply

<u>Some geographical areas</u> (e.g. SEA, Japan,...)

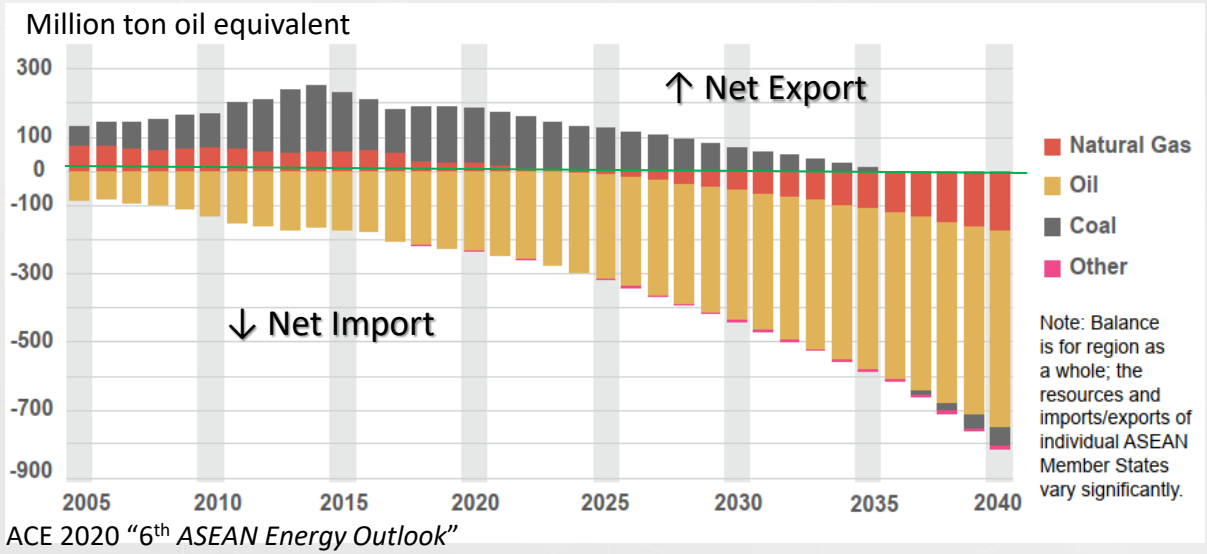
› **Energy deficit** → import of fossil energy today
& green energy in the future

Conversion Reconversion

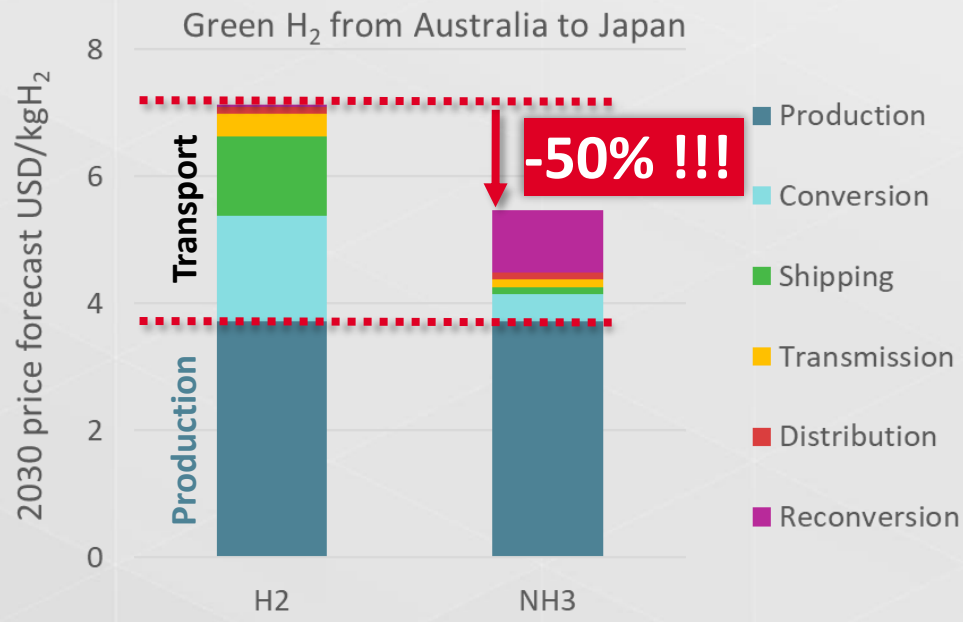
<u>Import via ship</u>: H_2 → NH_3 (for shipping) → H_2

› NH_3 liquefaction only at -33°C vs H_2 at -253°C

› NH_3 infrastructure already exists! (>200 port terminals)



ACE 2020 "6th *ASEAN Energy Outlook*"



IEA 2019 "*The future of hydrogen*"

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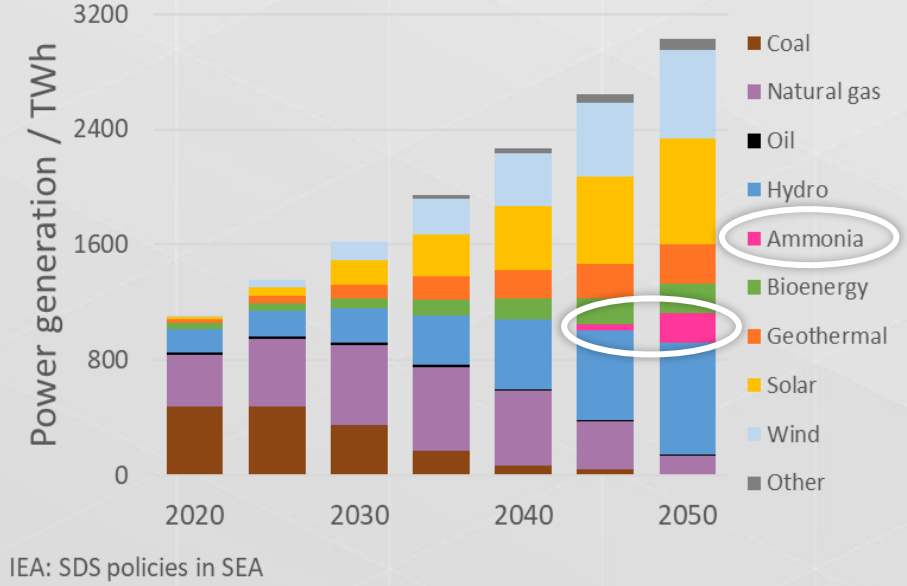
Huge momentum for NH_3 utilization

Maritime fuel: Maersk, BHP, Rio Tinto,..

Co-firing power plants:

› **In Japan:** Ministry for Economy Trade & Industry (METI)
15 TWh → 150 TWh
(2030) (2050)

› **In SEA:** Sustainable development scenario policies



IEA: SDS policies in SEA

Ammonia will be used

©Google Maps

SK Inc. to supply ammonia import for co-firing KOEN power plants

METI: Green Growth Strategy
Roadmap for fuel ammonia
Ammonia Energy Council
IHI, JERA, MHI, JGC, ...

TGS with thyssenkrupp, Black&Veatch
study on green ammonia production plant

Tenaga Nasional with IHI & Petronas ammonia co-firing tests in Kajang

Thailand, Singapore, Indonesia: cooperation with Japanese METI on ammonia co-firing

Jurong Port in Singapore: Study with MHI & JERA for a 100% 60MW ammonia power plant

BHP signs letter of intent for **Australia-East Asia iron ore green corridor** using green ammonia

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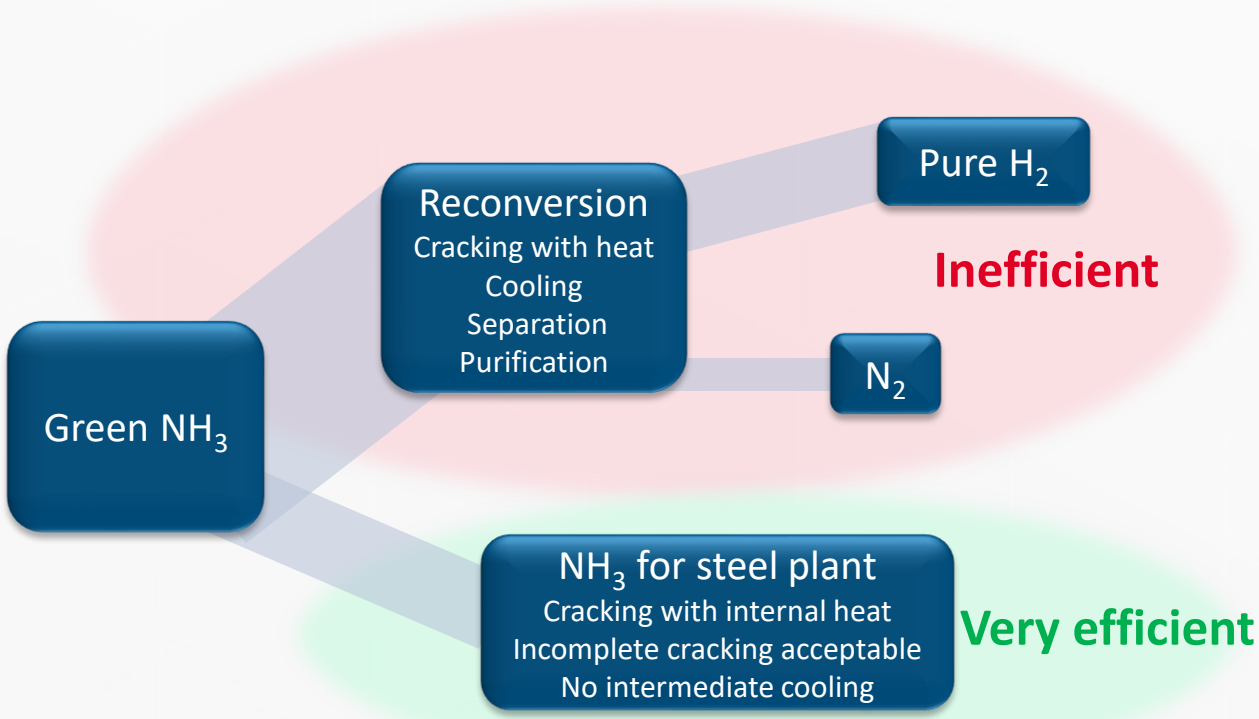
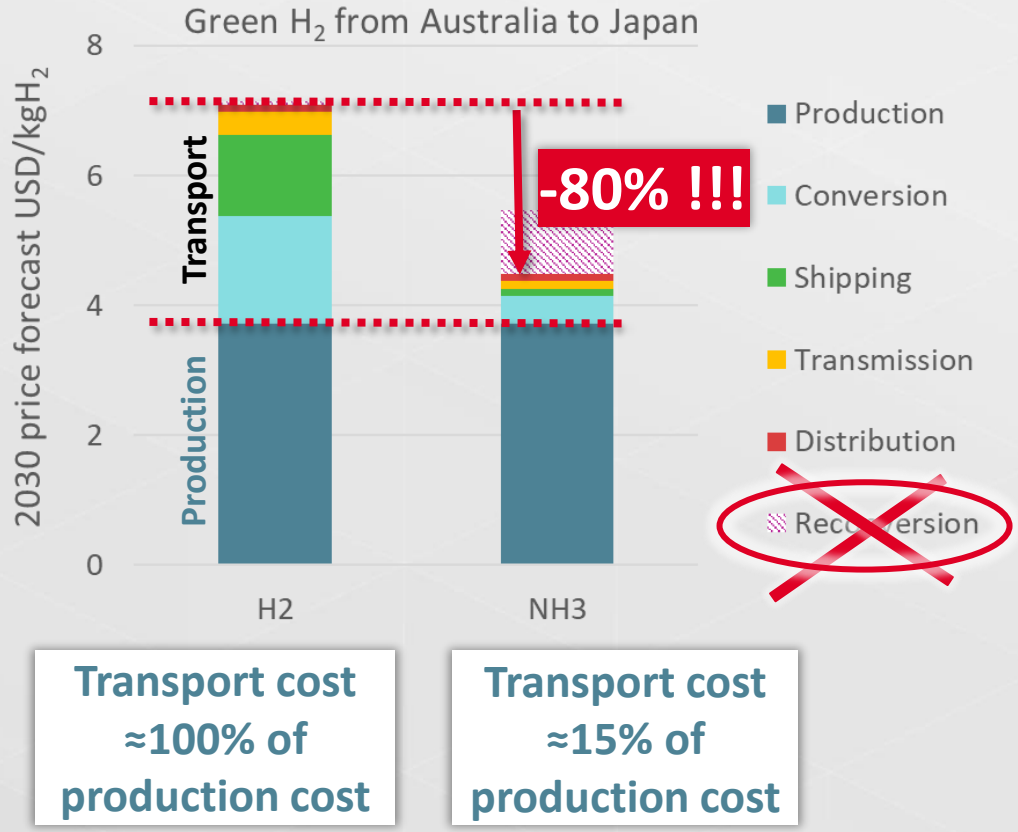
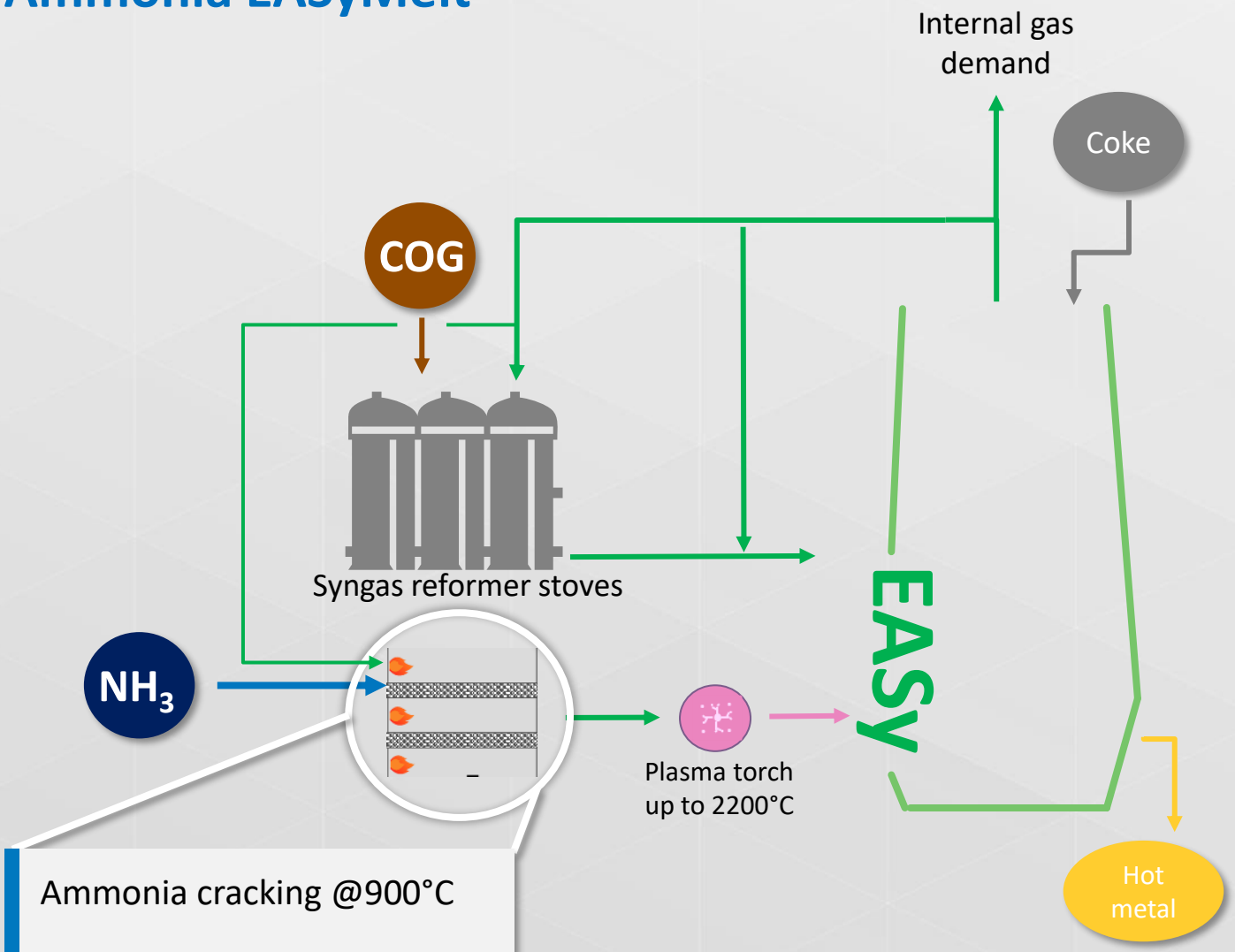
Advantage of the steel industry using green NH_3

- Fuel cells/chemical industry: **reconversion cost**
- Steel industry: **direct usage** possible





Ammonia EASyMelt™



Ammonia cracking @900°C

$2\ NH_3 \rightarrow N_2 + 3\ H_2$

"Cracked ammonia"

Patent pending

Successful reduction test of pellets @800°C with cracked ammonia **by Paul Wurth SMS**

>95% metallization

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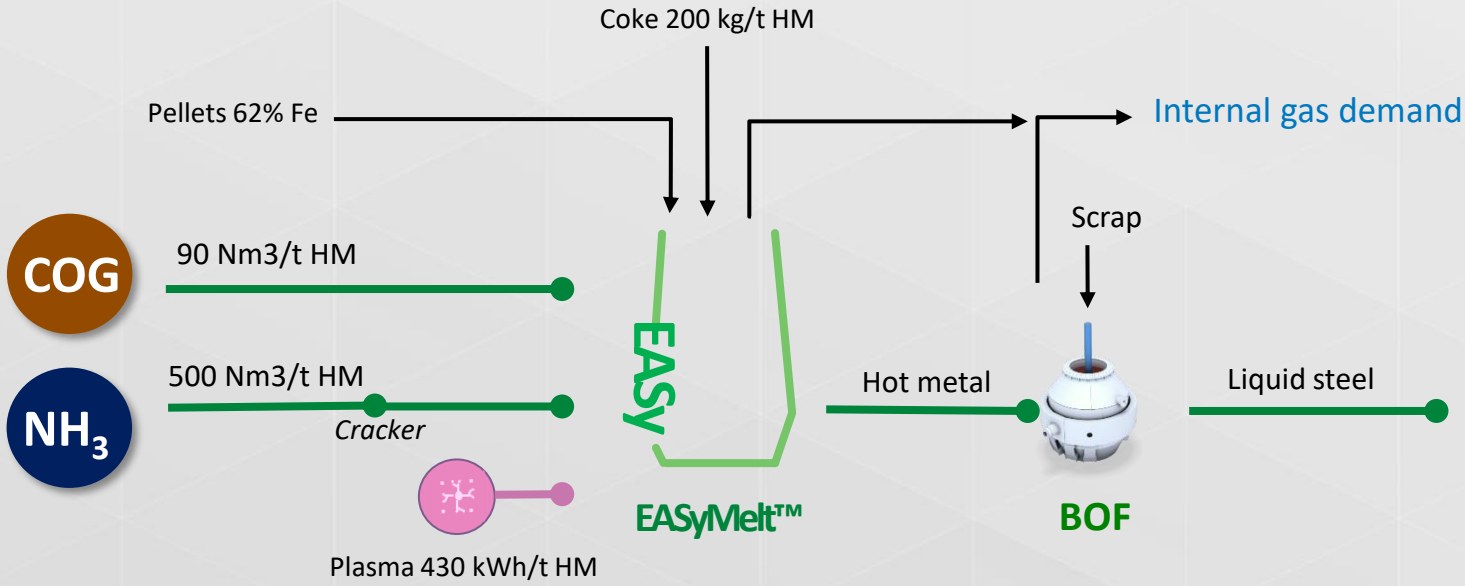
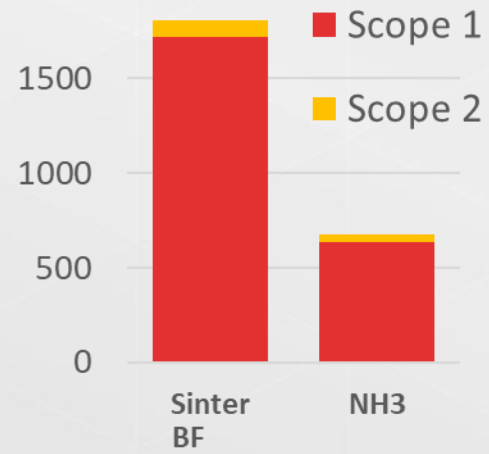
EASyMelt™ low carbon furnace 200 kg coke rate with NH_3



CO_2 emissions [kg/t LS]



OECD EU-28, emission factor of 80kg/MWh (target 2050)

› **Huge reduction thanks to NH3 import**

CO_2

676 kg/t LS

-62%

Import HBI as carrier for green energy

Lower transportation costs

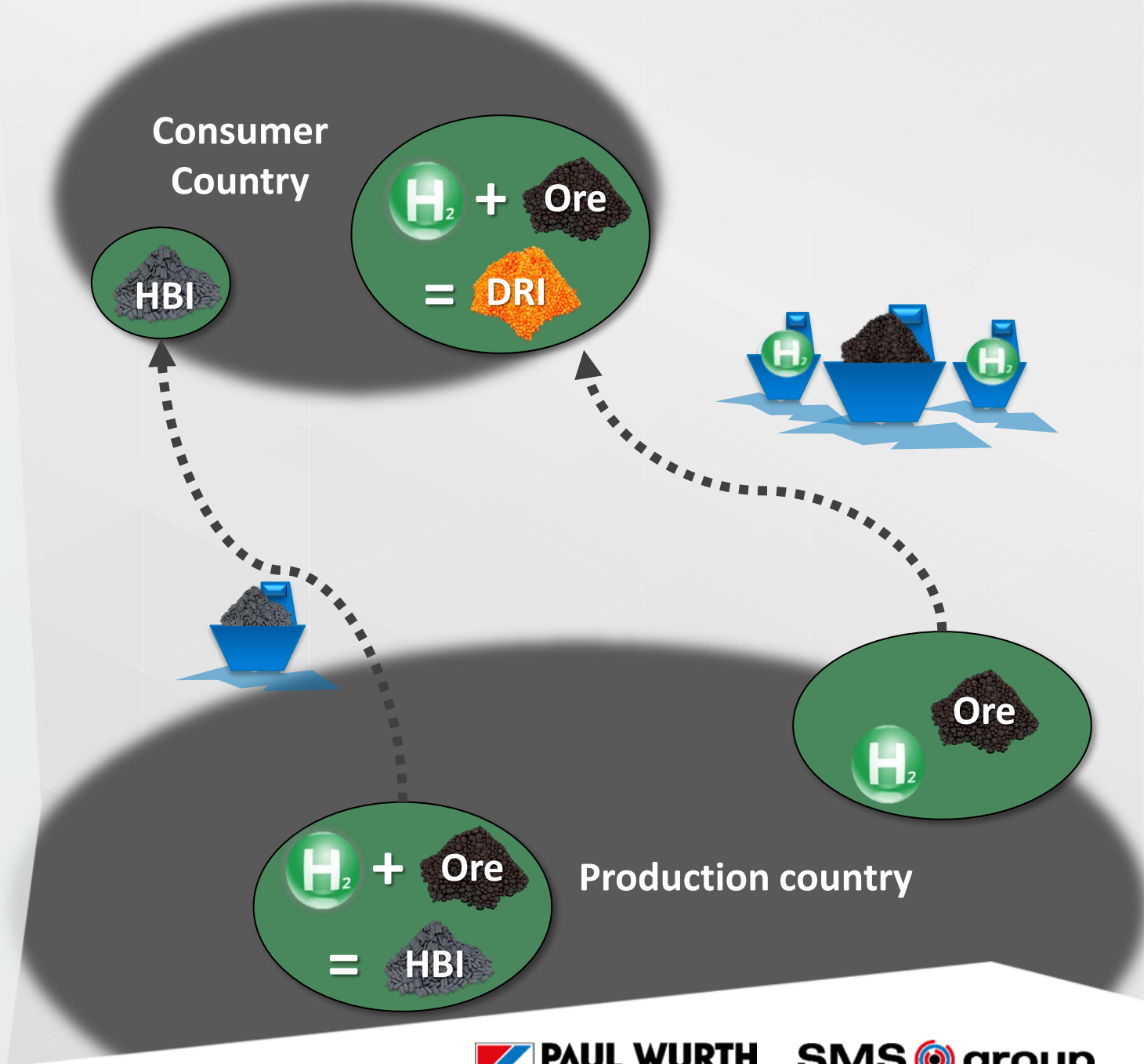
- Easy handling/storage compared to LH_2
- Lower mass to be transported (no O_2)

Reduced local energy requirement

- Reduced energy importation costs

Import overseas HBI

- Ideally used in a DR-smelting process
- **EASyMelt™ shaft injection enables** maximum HBI amount & efficiency



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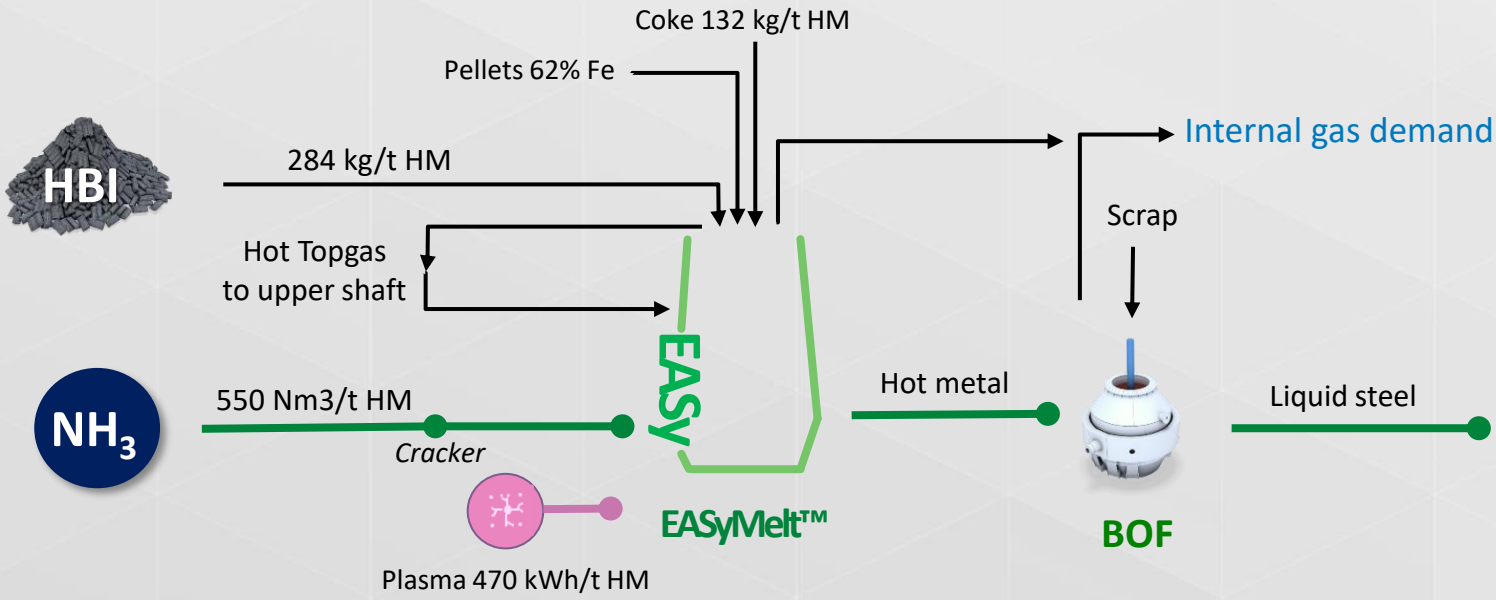
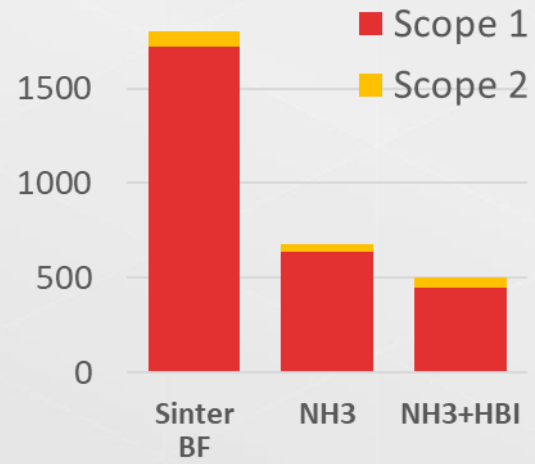
EASyMelt™ low carbon furnace 132 kg coke rate with NH_3 and HBI



CO_2 emissions [kg/t LS]



OECD EU-28, emission factor of 80kg/MWh (target 2050)

› **Huge reduction thanks to efficient HBI usage**

CO_2

503 kg/t LS

-72%

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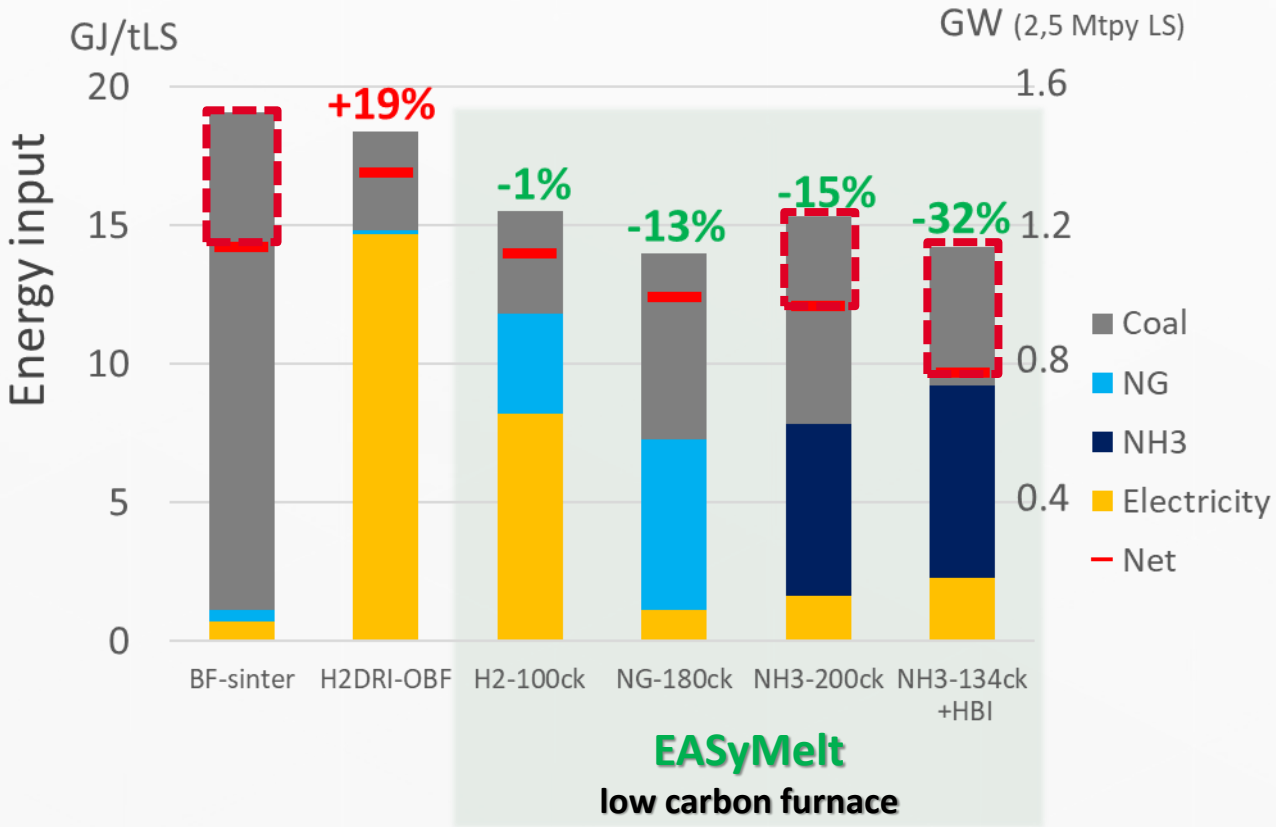
Energy input



Energy efficiency with EASyMelt™

- Less energy import, lower net input
- Low local green electricity demand
- Enough export gas to maintain power plant with NH3!

Steelmakers can remain **independent of local energy supply!**

Outlook for the EASyMelt™

Paul Wurth new concept

- ✓ Maintain existing plant setup & low CAPEX
- ✓ Use ore from traditional mining operations
- ✓ Flexible green energy usage: H2 and NH3

Low risk concept steps

- ✓ Flexible implementation according to political requirements
- ✓ Individual technologies all have already been used at industrial scale
- ✓ PW development since 3 years: pilot plant dry reformer, completed engineering for shaft injection, …

Next step

➡ Collaboration with steel plant partner to stepwise industrialize EASyMelt™

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