DANIELI

TRANSITION TECHNOLOGIES TO DANIELI ECOLOGICAL AND QUALITY ELECTRIC STEELMAKING USING SCRAP AND ENERGIRON® DRI

ANTONIO SGRO'
Vice President
Danieli Green Metal

2022 SEAISI Steel Mega Event & Expo

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PASSION TO INNOVATE
AND PERFORM
IN THE METALS INDUSTRY

DANIELI GREEN METAL

H2 READY DANIELI

DANIELI TEAM
MORE THAN
A CENTURY
OF PARTNERSHIP
EXPERIENCE

INDEX

INDEX

ROAD TO CO2 EMISSIONS REDUCTION- STEELMAKING TRANFORMATION

GROWTH OF STEEL DEMAND

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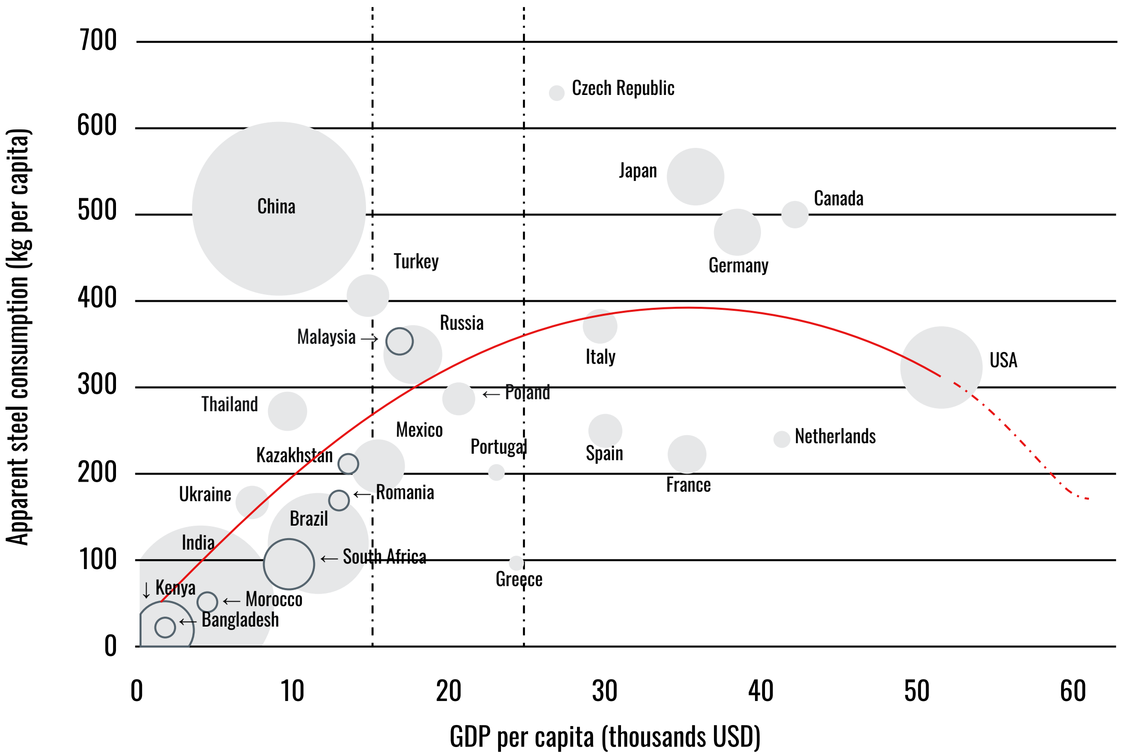
- Global demand for steel is forecast to increase by more than a third through to 2050 (in 2020 was 1.88 billion ton and of this 73% was made via the BF-BOF process)
- Iron stocks plateau is of about 10-12 tons per capita.
- The global average iron stock was about 4.0 tons per capita (2015) and it is forecast to be 7.0 tons in 2050 with a world population of 9.8 billion
- Steel scrap use will increase dramatically against a quite stable pig iron production

Intensity of Metal Use IUt = $f(GDP_t/Capita_t)$

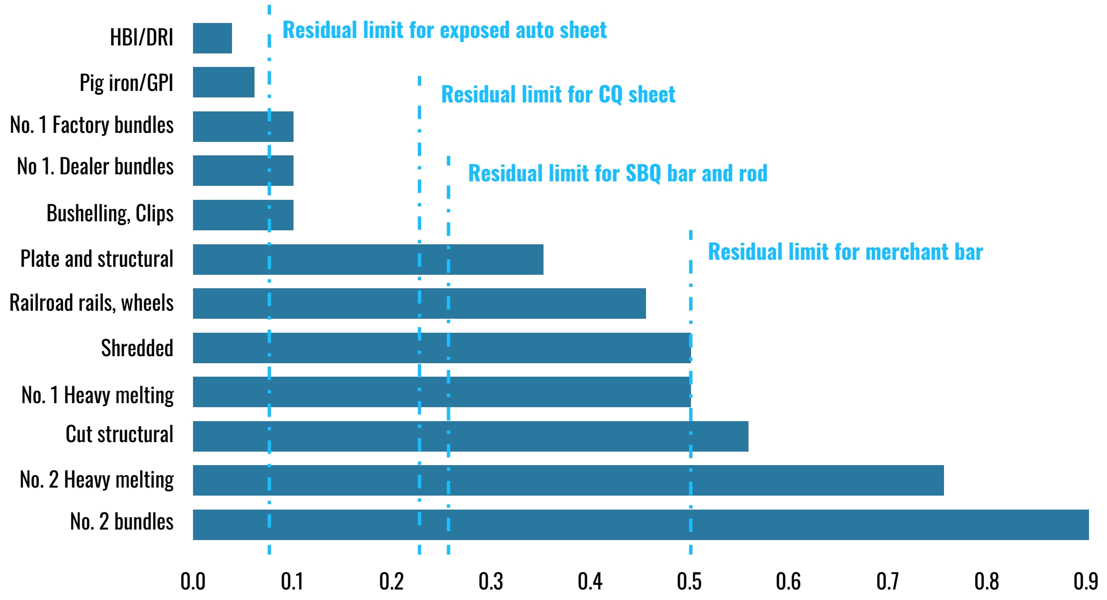


Source: A. Paulo, M. Krzak "Evolution of technology and the market of steel raw materials"

SCRAP AND METALLIC RESIDUALS

- The Electric Arc Furnace (EAF) using 100% scrap as feedstock is currently the technology with the lowest carbon footprint
- Available scrap amount will increase drastically in next decades (mainly Asia)
- A better scrap classification based both on physical and chemical properties (home, prompt, obsolete scrap) will be the base for all grades steel production
- High-quality steel grades production needs dilution of residuals by virgin iron notably if obsolete scrap is used

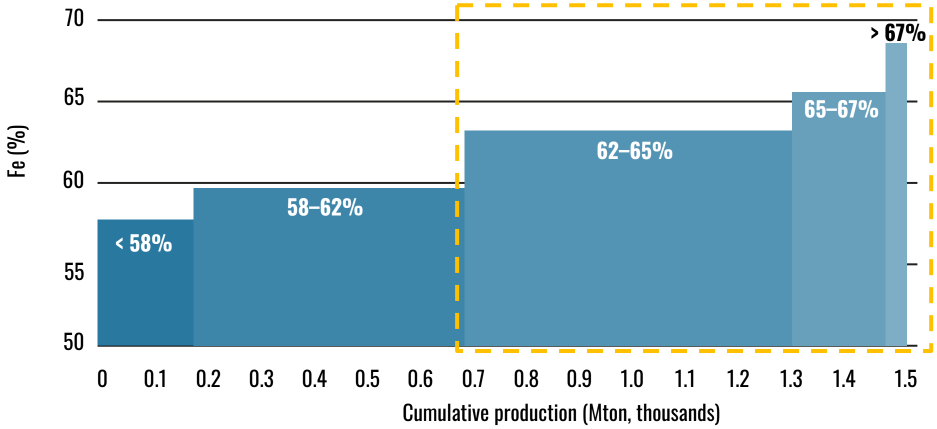
Metallic feed residual levels for various steel products

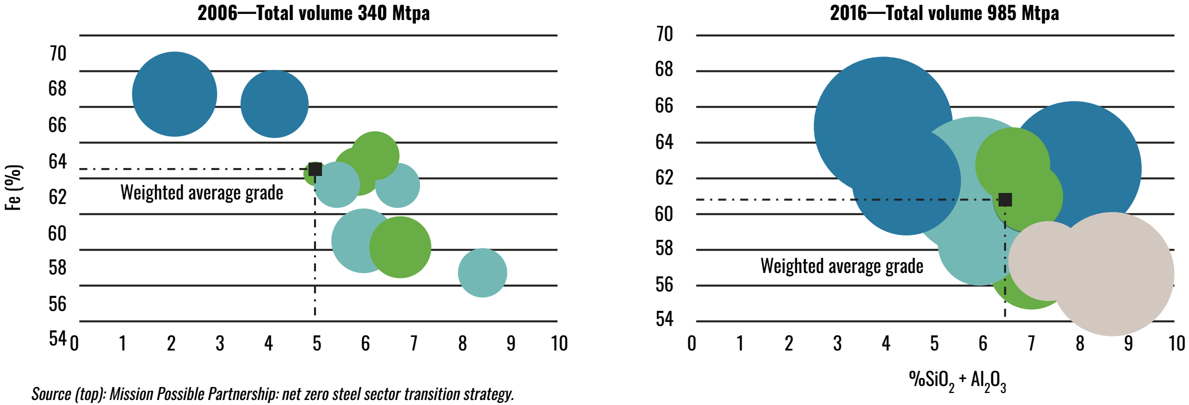


Source: J.Jones,AisTech 2022

IRON ORE QUALITY

- Declining of average quality of iron ore has led to declining the productivity and increasing the energy intensity as well as the potential environmental impact
- Available iron resources must also be linked to impurities in iron ores such as phosphorous (%P), silica (%SiO_2), alumina (%Al_2O_3)
- Focus on the development of mines (high quality iron ores), beneficiation to improve the grade of the existing ore and technology solutions to use lower grade iron ore in DRI processes.





Big four miners %Fe and acid gangue:

Vale RTIO BHP FMG

Source (top): Mission Possible Partnership: net zero steel sector transition strategy.
Source (bottom) Minerals Council of Australia.

DRI QUALITY

- DRI produced from blast furnace pellet grades is categorized as “low quality material” since characterized by:
  - Low iron content (typical range from 62% BF pellet is 82% vs 92%)
  - High amount of gangue (typical range 12÷17% vs >5%)
- The difference in price between BF and DR grade depends on the market profitability, environmental policies metallurgical coal prices
- A conservative price difference is 15€/t (DR grade vs BF grade)

	DR Pellet (%)	DRI (%)
Total Iron	67.8	91.77
Fe2O3	96.94	0
FeO	0.00	7.08
Fe	0	86.27
Carbon	**0**	**2.50**
Total Gangue	**3.06**	**4.15**
SiO2	1.49	2.02
Al2O3	0.43	0.58
CaO	0.74	1.0
MgO	0.05	0.07
P	0.02	0.02
S	0.00	0.00
Others	0.33	0.46

	BF Pellet (%)	DRI (%)
Total Iron	62	81.80
Fe2O3	88.24	0
FeO	0.36	6.27
Fe	0	76.31
Carbon	**0**	**2.50**
Total Gangue	**11.40**	**14.92**
SiO2	4.31	5.64
Al2O3	1.08	1.41
CaO	2.60	3.40
MgO	1.54	2.02
P	0.03	0.04
S	0.02	0.02
Others	1.82	2.39

INDEX

ROAD TO CO2 EMISSIONS REDUCTION- ENERGIRON AND DIGIMELTER STRATEGY

DANIELI TECHNOLOGIES FOR GREEN STEEL PRODUCTION

TECHNOLOGICAL SOLUTIONS PRIMARY STEEL PRODUCTION

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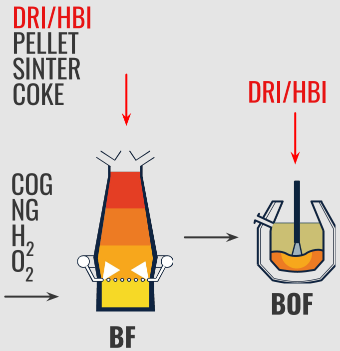
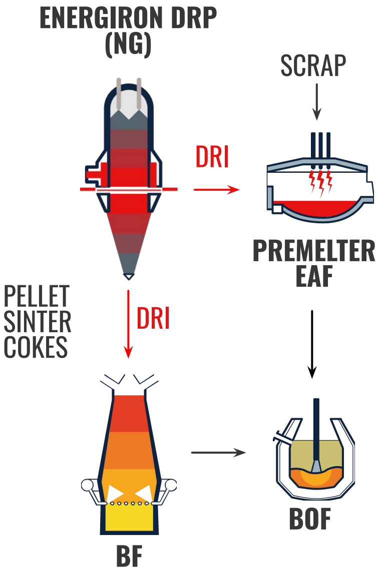
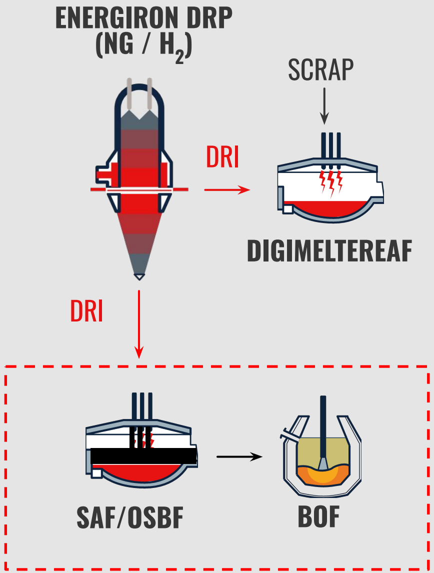
OPTIMIZATION



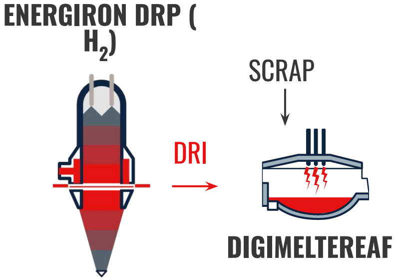
PARTIAL TRANSITION



PARTIAL TRANSITION #2



FULL TRANSITION



FULLY SUSTAINABLE STEELMAKING

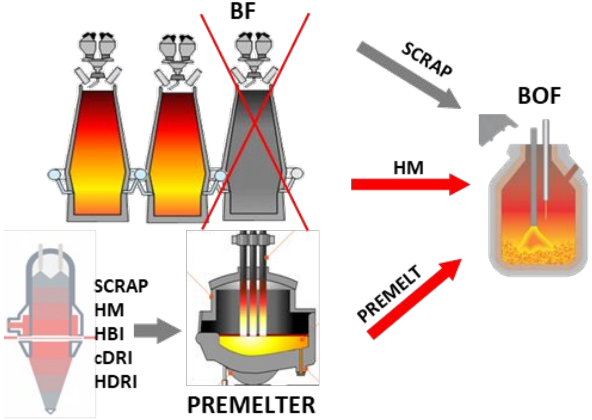
PREMELTER ROUTE

Pro's

+ From BOF to final product the production route is the same as per BF-BOF: same steel quality
+ PreMelter is a conventional EAF with higher carbon at tapping
+ PreMelter can be converted to DRP-DDM in future, overcoming BOF
+ Higher flexibility for raw materials in input

Con's

- Installation requires reconfiguration of existing HM sourcing
- Sufficient availability of scrap and/or cDRI/HBI to feed the PreMelter



Low capex

No need of local DRP

Premelter can be converted to std DDM in future

Not suitable for all integrated plants

CO_2 reduction limited to 30%-35% vs BF-BOF

Same production route as per BF/BOF

No need of new certification

→ Up to AUTOMOTIVE EXPOSED

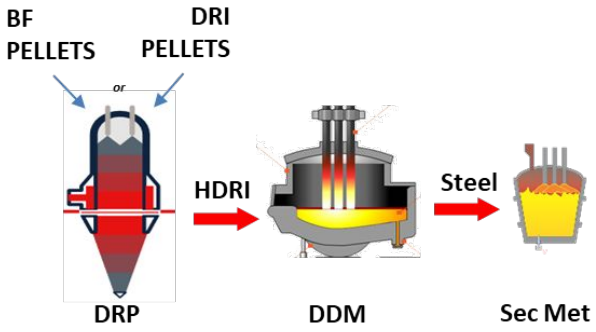
DRP-DIGIMELTER ROUTE

Pro's

+ Consolidated technology
+ DRP-DDM Meltshop is flexible to select the right pellet grade according to the production mix
+ High productivity with DR grade pellets
+ Significant CO2 footprint reduction
+ Hydrogen ready for future without any modification
+ DDM can be designed to operate also with low grade DRI pellets

Con's

- It requires modification of overall process and re-certification of production protocols (when required)
- Larger quantity of slag to be disposed as lower is the grade of BF pellets



High quality pellets

Quantity limited on the market

— Higher yield

Higher steel quality

→ Up to AUTOMOTIVE EXPOSED

Low quality Pellets,

Same sourcing of BF

— Low yield

High quantity of slag

→ ONLY for Construction steel grades

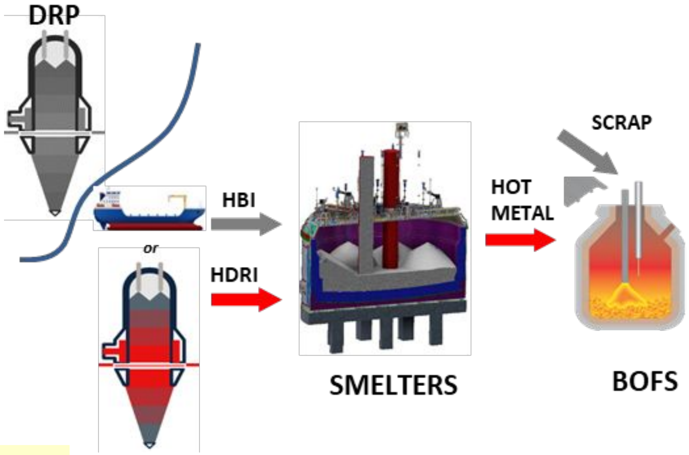
SMELTER-BOF ROUTE

Pro's

+ From BOF to final product the production route is the same as per BF-BOF: same steel quality
+ Slag composition is similar to BF one with a very low content of FeO

Con's

- Smelter productivity shall be scaled up significantly (>> 1MTPY) compared to the current state of the art
- Multiple Smelters can be required to couple with the production of one DRP plant
- If a DRP plant cannot be installed locally, the use of HBI becomes critical due to high power required for melting



Low quality BF Pellets,

Same slag as BF

HBI melting to be investigated

(Ferrobergs vs breakout)

Multiple Smelters for high prod.

Smelter technology to be developed

Same production route as per BF/BOF

No need of new certification

→ Up to AUTOMOTIVE EXPOSED

CO_2 MITIGATION STRATEGIES

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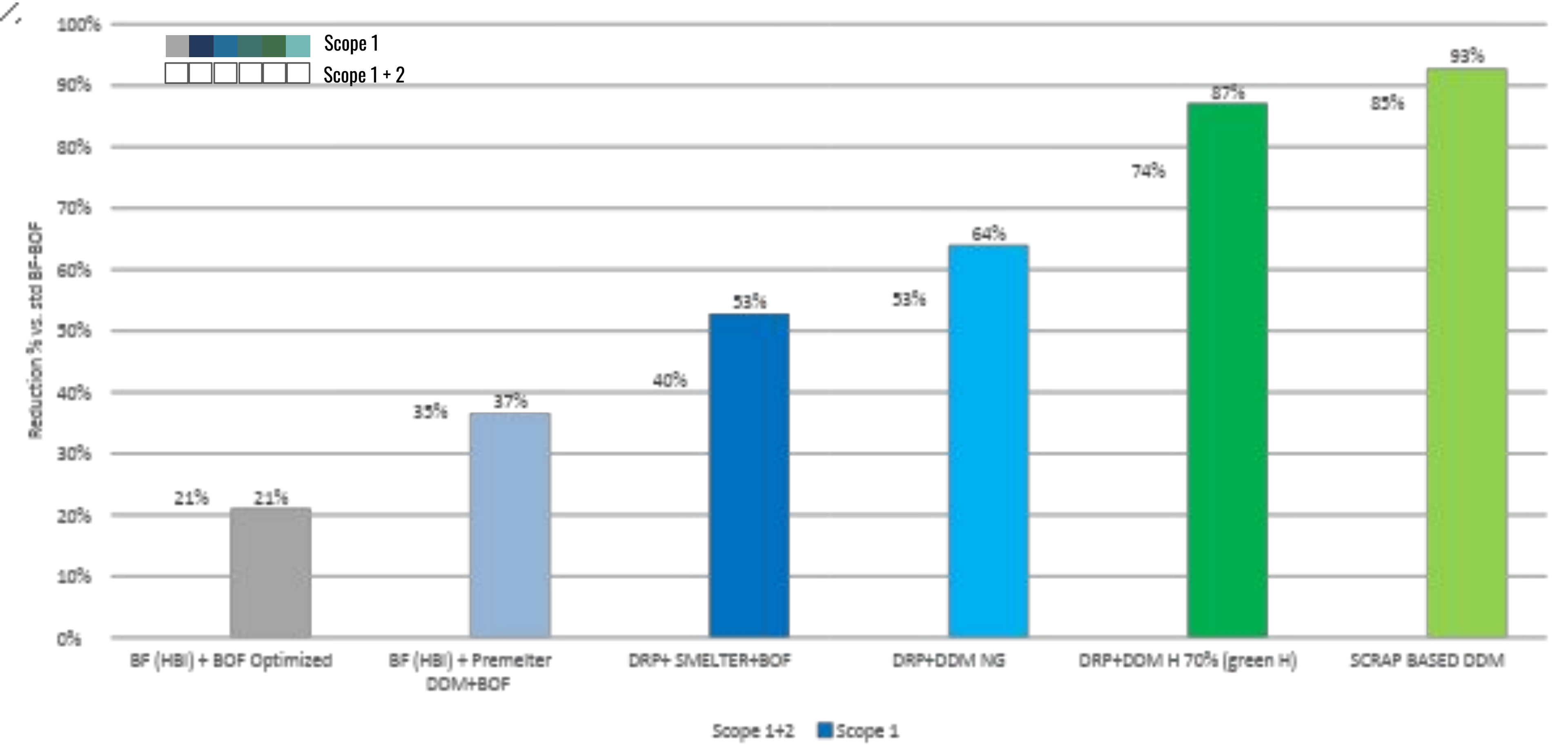
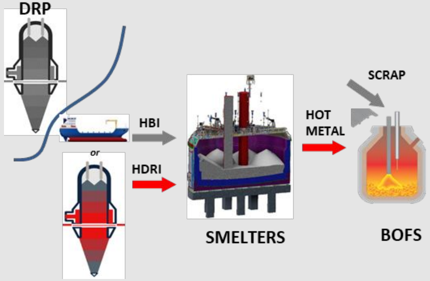


INDEX

ROAD TO CO2 EMISSIONS REDUCTION- ROUTES COMPARISON BY EMISSIONS AND OPEX

ROUTES COMPARISON

Smelter process route



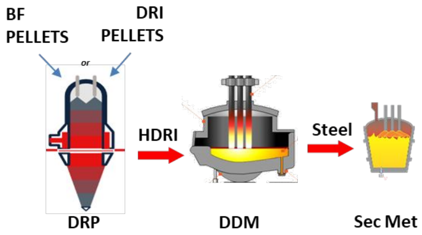
Simulation with:

- BF grade pellet (81% total iron)
- BF pellets 108 €/t (source Kallanish)
- DRI with Metallization 94% and 2,5% C
- 20% of scrap on the BOF
- CO2 tax 80€/t

Production Cost [€/t]		407
Emission Scope 1 [kgCO_2/t]		685
Production Cost [€/t] with CO2 tax		462

- High OPEX
- Much Higher CAPEX
- Higher CO2

DRI + DDM process route – BF grade pellets



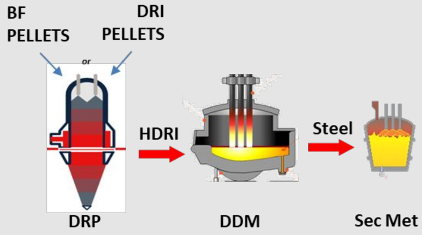
Simulation with:

- BF grade pellet (81% total iron)
- BF pellets 108 €/t (source Kallanish)
- DRI with Metallization 94% and 2,5% C
- 20% of scrap on the BOF
- CO2 tax 80€/t

Production Cost [€/t]		402
Emission Scope 1 [kgCO_2/t]		606
Production Cost [€/t] with CO2 tax		451

- Mid OPEX
- Low CAPEX
- Low CO2

DRI + DDM process route – DR grade pellets



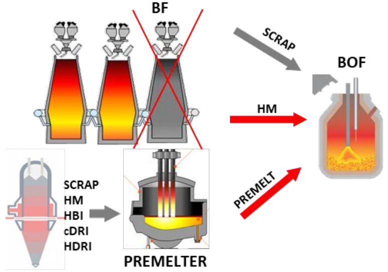
Simulation with:

- DR grade pellet (total iron 91,8%)
- DR pellets 126 €/t (source Kallanish)
- DRI with Metallization 94% and 2,5% C
- 20% of scrap on the DDM
- CO2 tax 80€/t

Production Cost [€/t]		382
Emission Scope 1 [kgCO_2/t]		523
Production Cost [€/t] with CO2 tax		424

- Lowest OPEX
- Low CAPEX
- Lowest CO2

Transition Phase – PreMelter



Simulation with:

- 30% HM substituted by Premelt
- 100% Scrap DDM for premelt @ 1,6% C
- 20% of scrap on BOF
- CO2 tax 80€/t

Production Cost [€/t]		433
Emission Scope 1 [kgCO_2/t]		920
Production Cost [€/t] with CO2 tax		506

- Higher Opex (for limited time)
- Very Low CAPEX
- Mid CO2

CO_2 MITIGATION STRATEGY VS PRODUCTION COST

Mitigation Strategy

Phase 1 – (2021-2030)

- PreMelter (DDM technology)
- Immediate CO_2 reduction (more than 30%)
- BOF route still available
- Very Low Capex

Phase 2 – (2030 →)

- Complete shutdown of BF-BOF route
- Easy conversion to the DRP-DDM route
- Further CO_2 reduction (up to 100% with hydrogen use and carbon capture)
- Shutdown Lower CapEx and OpEx

ROUTES COMPARISON

Reference BF-BOF	BENCHMARK	*PREMELTER*	SMELTER	DDM DRI LOW QUALITY	DDM DRI HIGH QUALITY
345	Production Cost [€/t]	*433*	407	402	382
1435	Emission Scope 1 [$kgCO_2/t$]	*920*	685	606	523
460	Production Cost [€/t] with CO2 tax	*506*	462	451	424

Transition phase

Final phase

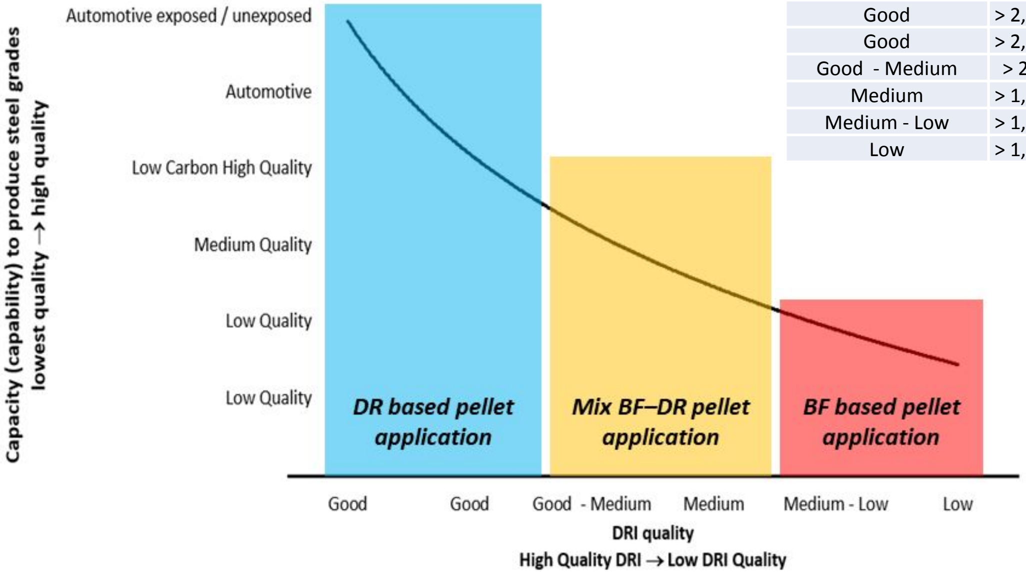
Limited time according to the Company business plan

ROAD TO CO2 EMISSIONS REDUCTION- ROUTES COMPARISON BY STEEL QUALITY

DRI QUALITY VS STEEL GRADE QUALITY

Steel grades to be produced using DRI as raw material

- Based on steel grade requirement a vacuum treatment shall be considered for nitrogen removal
- Different mix between DRI and scrap shall be considered based on steel quality requirements (metallic residuals, nitrogen content



DRI quality	Reference DRI quality	
	%C	% Gangue
Good	> 2,4%	≤ 5%
Good	> 2,4%	≤ 5%
Good - Medium	> 2%	≥ 5% ≤ 8%
Medium	> 1,5%	> 8% ≤ 10%
Medium - Low	> 1,5%	> 10% ≤ 14%
Low	> 1,5%	> 14%

	Reference steel grade chemistry			
	%C	N, ppm	%P	%S
Automotive exposed / unexposed	max 0,005	30÷50	0,012	0,008
Automotive	max 0,06	max 50	0,012	0,008
Low Carbon High Quality	max 0,08	max 50	0,015	0,008
Medium Quality		max 70	0,018	n/a
Low Quality		max 100	0,02	n/a
Low Quality		max 120	0,025	n/a

TECHNOLOGICAL SOLUTIONS
NEW CONCEPT OF MELTING

DRP-DDM challenges for BF pellets

- Higher amount of slag as gangue increase (up to 40%)
- Higher slag volume (foaming)
- Higher FeO content in slag (20-30%)
- Higher electrical consumption (anyway less than smelter)
- New production strategies and equipment

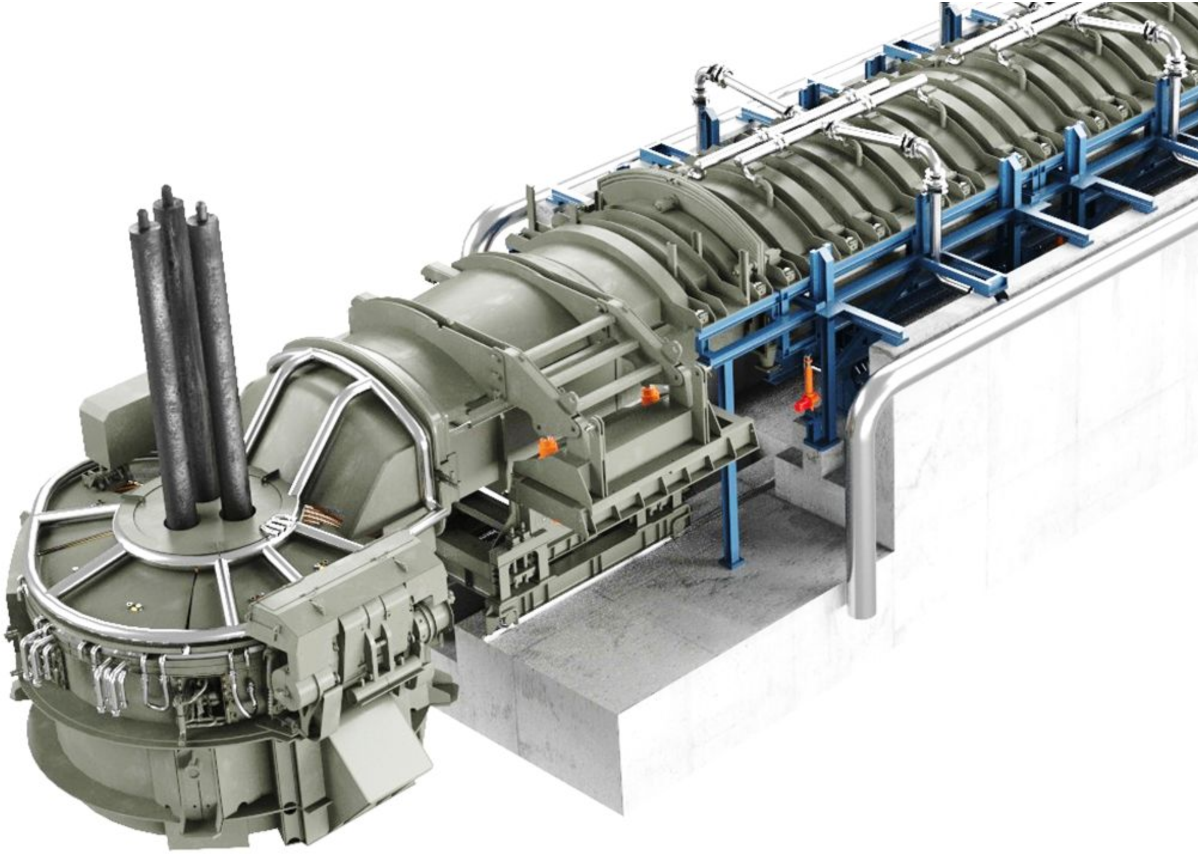
DRP-DDM benefits

- Higher flexibility in a wide range of steel grade also with BF pellets
- Burden mixing strategy
- Lower CapEx and OpEx
- Ability to produce also automotive exposed with DR-pellets charge

DIGIMELTER

The system to accomplish BF pellets melting.

- **Q-One technology provides**:
  - short current arc
  - high level of bath stirring by arc frequency variation (from 70 to 20 Hz)
  - infinite working points possible by no tap changer for secondary voltage control
- New EAF shell and slag door design to handle the increased slag amount
- Q-Melt technology for careful slag operations and slag analysis (basicity, viscosity, FeO)
- Wide range of operations with possible mixed materials feeding (DRI, scrap, hot metal)



TECHNOLOGICAL SOLUTIONS AN OVERALL PICTURE

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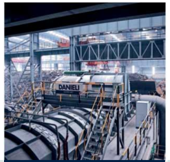
SCRAP MANAGEMENT



ENDLESS SCRAP CHARGE

DANIELI DIGIMELTER by Q-One

QSP-DUE®
Danieli Universal Endless for flat products

DYSEN-CASTER

Q-HEAT FLAT INDUCTION

QUALITY HOT-ROLLED STRIP

ENERGIRON & HYDROGEN FOR DRI PRODUCTION

DRI HOT CHARGE

HYBRID VIA Q-JENIUS

QLP-DUE®
Danieli Universal Endless for long products

OCTOCASTER

Q-HEAT LONG INDUCTION

BARS, WIREROD, MERCHANT SECTIONS

CONCLUSIONS

ROADMAP TOWARDS GREEN STEEL

The future for a steel with zero net emission will be achieved with:

- Electrification of the steel plant
- DRP – EAF route with use of natural gas and hydrogen
- Q-One/Digimelter technology for melting
- Investments in ore beneficiation and scrap upgrading for better Opex (leverage from 10 to 15 times) and less CO_2 emissions
- Circularly economy
- Carbon Capture Storage and Utilization
- Appropriate transition plan according to the Company business plan

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