Transformer go green

CO_2 reduced steel for the energy industry

15th December 2023 | Andrea Crespi
thyssenkrupp Steel Europe AG | Electrical Steel GmbH

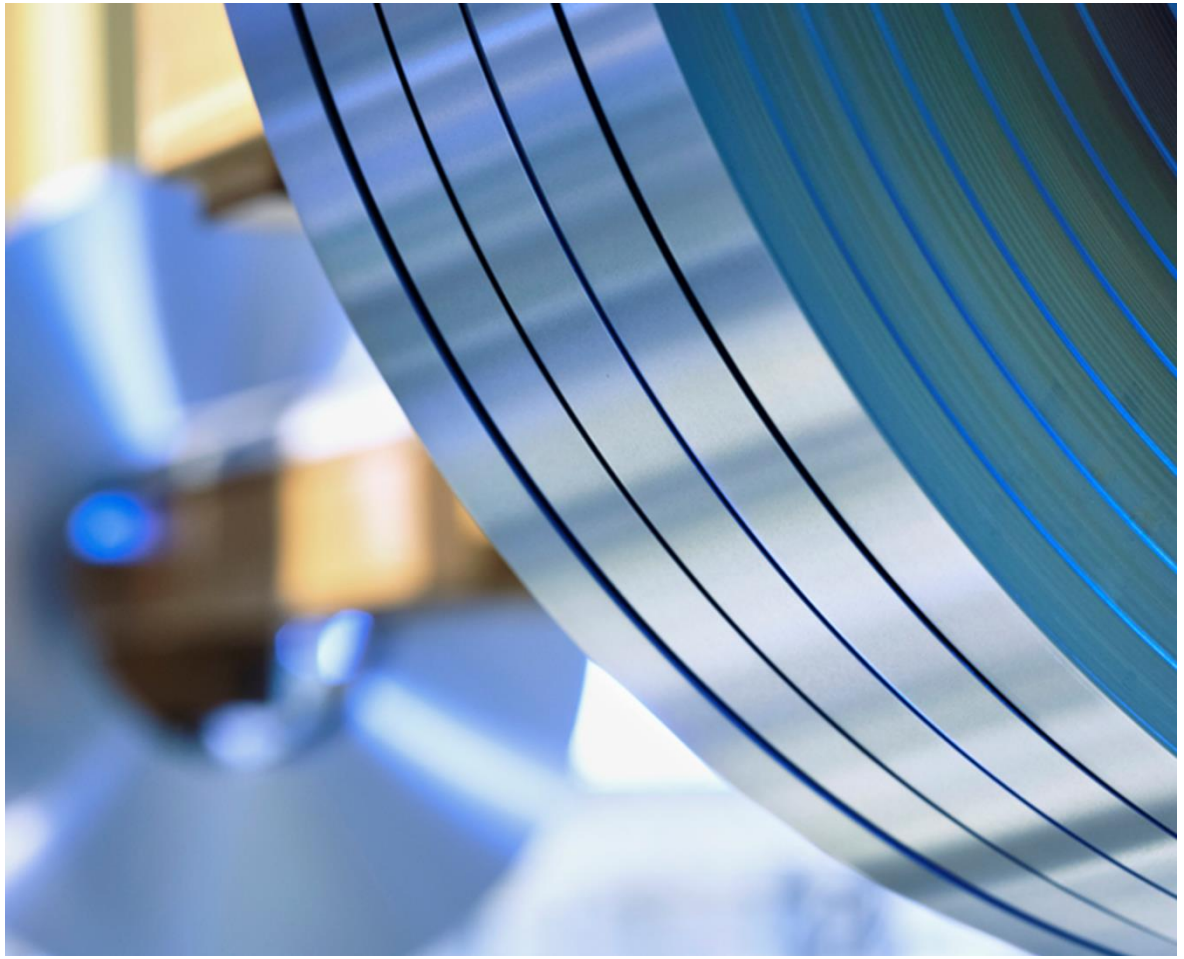
bluemint® Steel

engineering. tomorrow. together.

thyssenkrupp

Agenda

1. We are thyssenkrupp
2. About thyssenkrupp Electrical Steel
3. Digitalization & innovation
4. Green Transformation at thyssenkrupp Steel Europe
5. Bluemint® Steel – Solution for energy business
6. Bluemint® Powercore® core base for Green Transformer
7. Circular economy leverage & conclusion



Who we are

Germany's largest flat steel manufacturer

~ 10.5 m metric tons
crude steel p.a.

~ 26,300
employees

Automotive sector

Special vehicles

General industry

Power generation & turbines

thyssenkrupp

Consumer goods

Transformers & charging infrastructure

Structural elements

Packaging (e.g. cans and closures)

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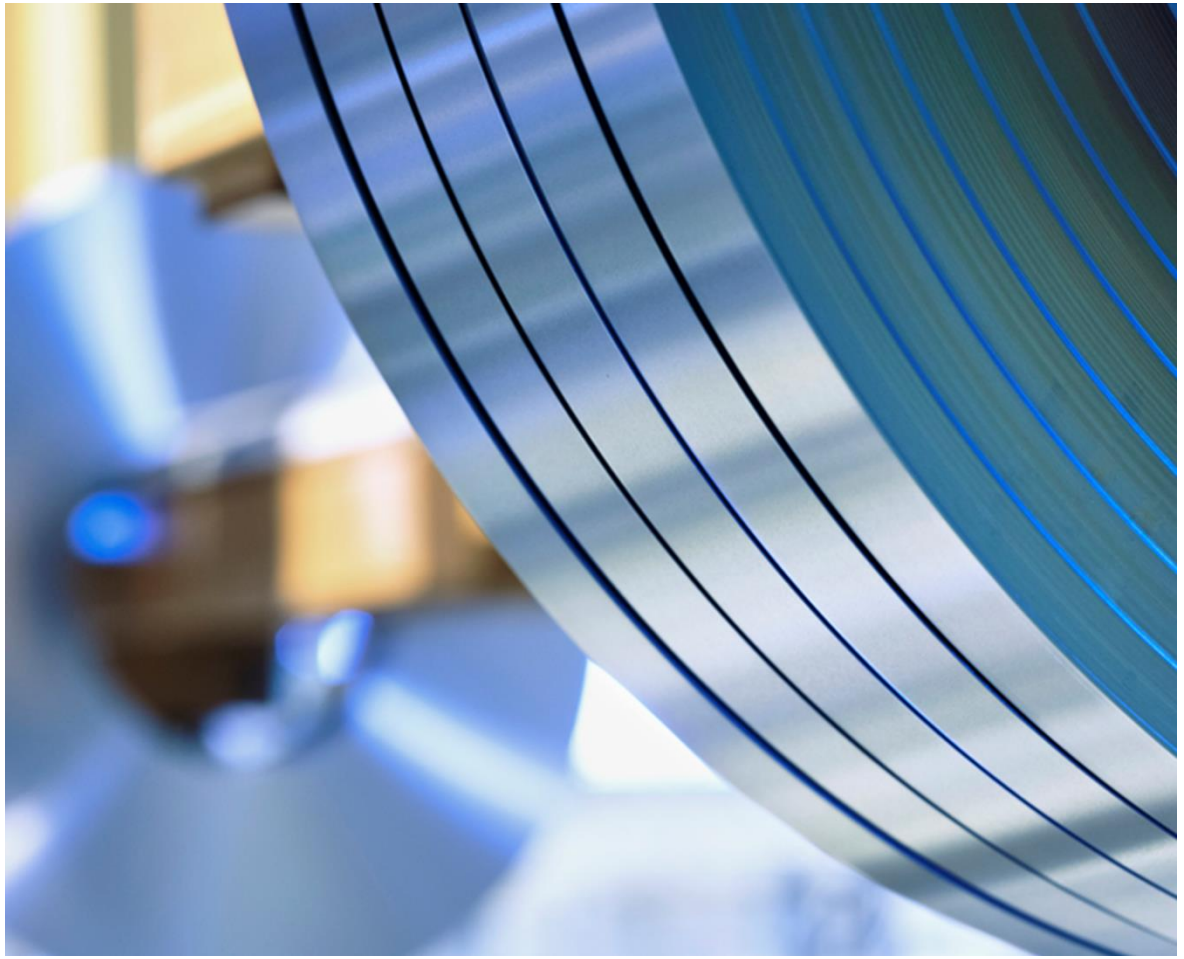


thyssenkrupp AG

thyssenkrupp Steel Europe

thyssenkrupp Electrical Steel

Plant Gelsenkirchen
Employees: 688
Area: 17 ha
Production volume: 75 kt/a

Plant Isbergues
Employees: 537
Area: 11 ha
Production volume: 75 kt/a

Plant Nashik
Employees: 501
Area: 62 ha
Production volume: 40+ kt/a

Top grades GOES – further development of low loss grades

Low noise performant GOES

Decarbonization strategy implementation

E-mobility with new drive concepts

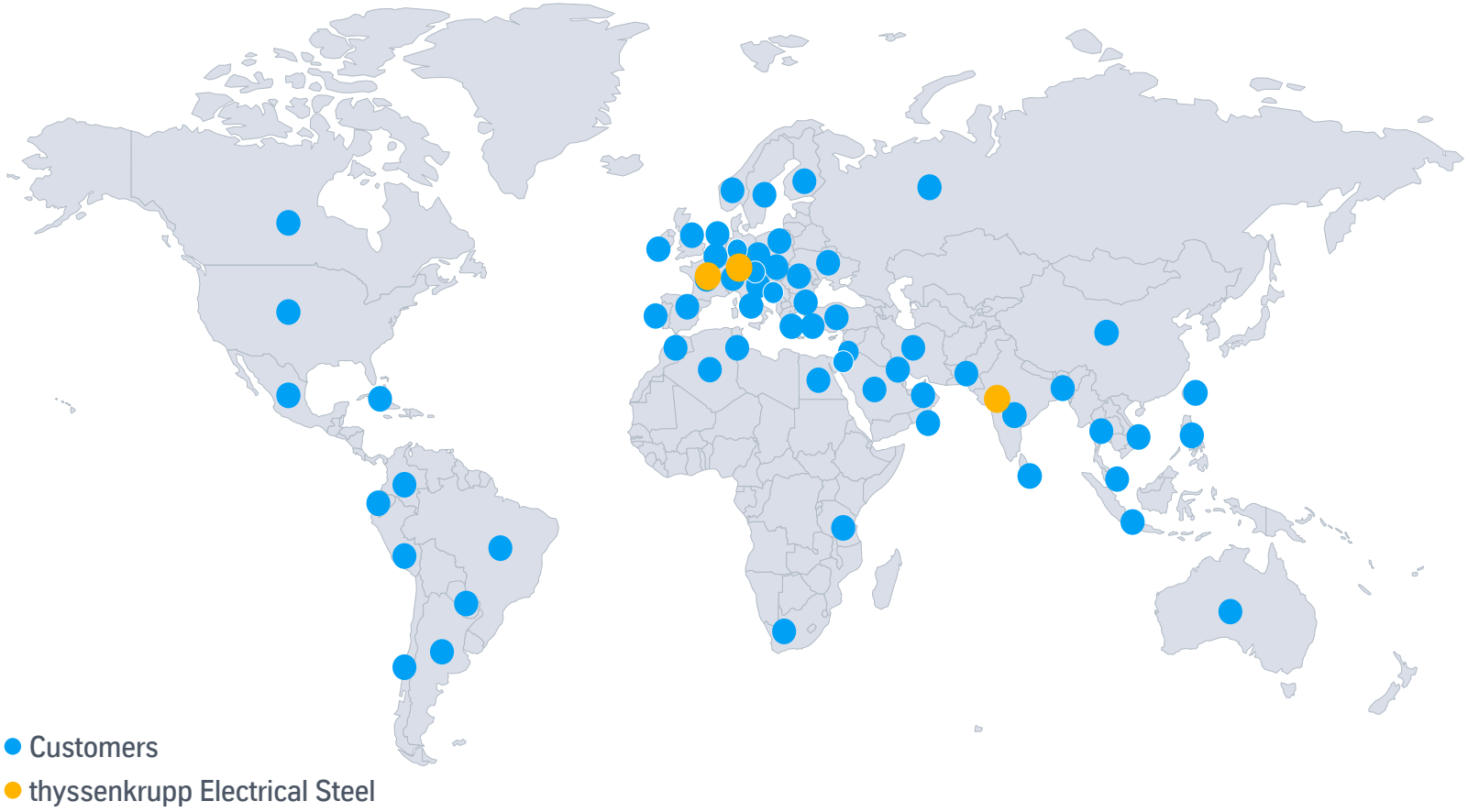
Material flow around the world

Production network thyssenkrupp Electrical Steel

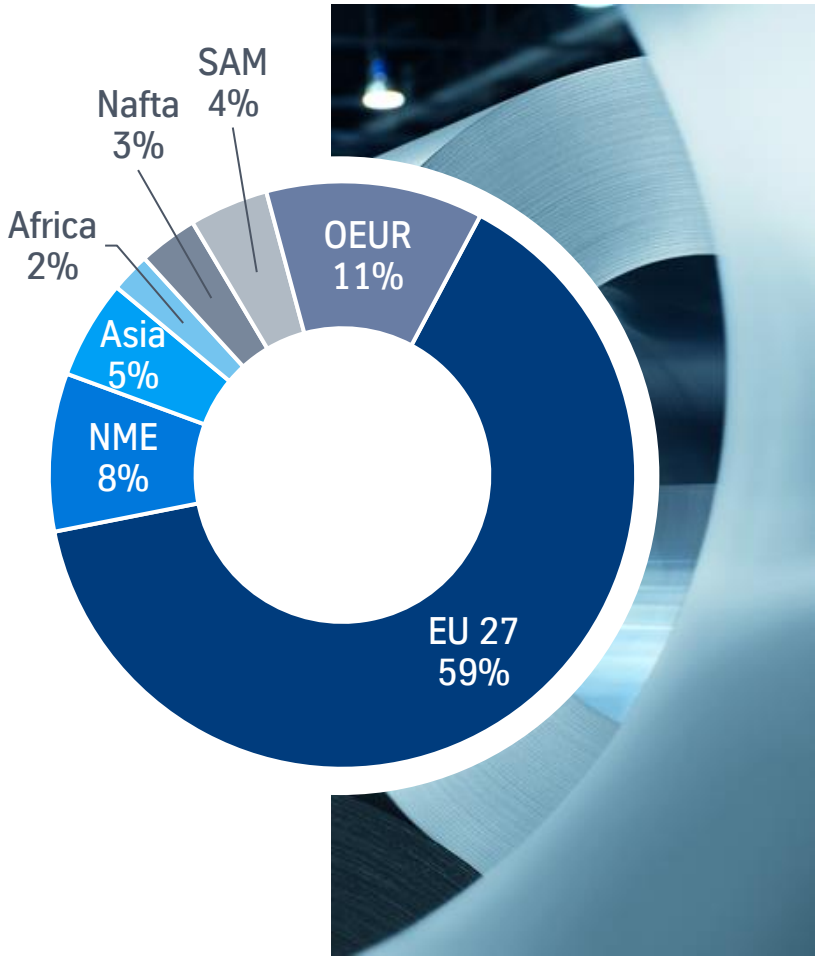
Sustainable customer relationships worldwide

Shipments by regions

More than 200 customers in 60 countries worldwide



● Customers
● thyssenkrupp Electrical Steel



Status: 2022 | IA

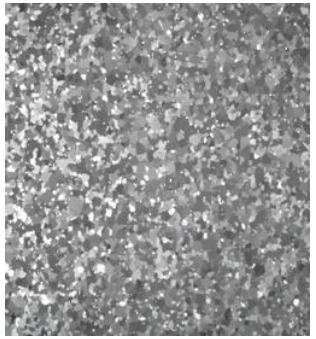
Grain oriented electrical steel

Electrical steel

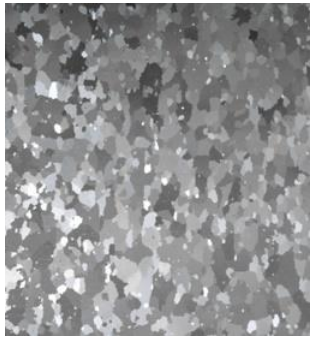
- Flat steel based on special iron-silicon alloys
- Technical capabilities:
  thickness 0,18 – 0,35 mm, width ≥ 6 – 1.040 mm
- Soft-magnetic material
- Carries and enhances the magnetic flux
- Its properties determine the efficiency of electric devices

Different grades of electrical steel

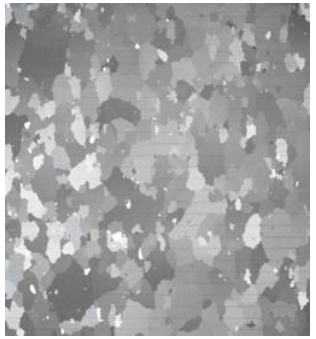
powercore® C



powercore® H



TOP-Grades



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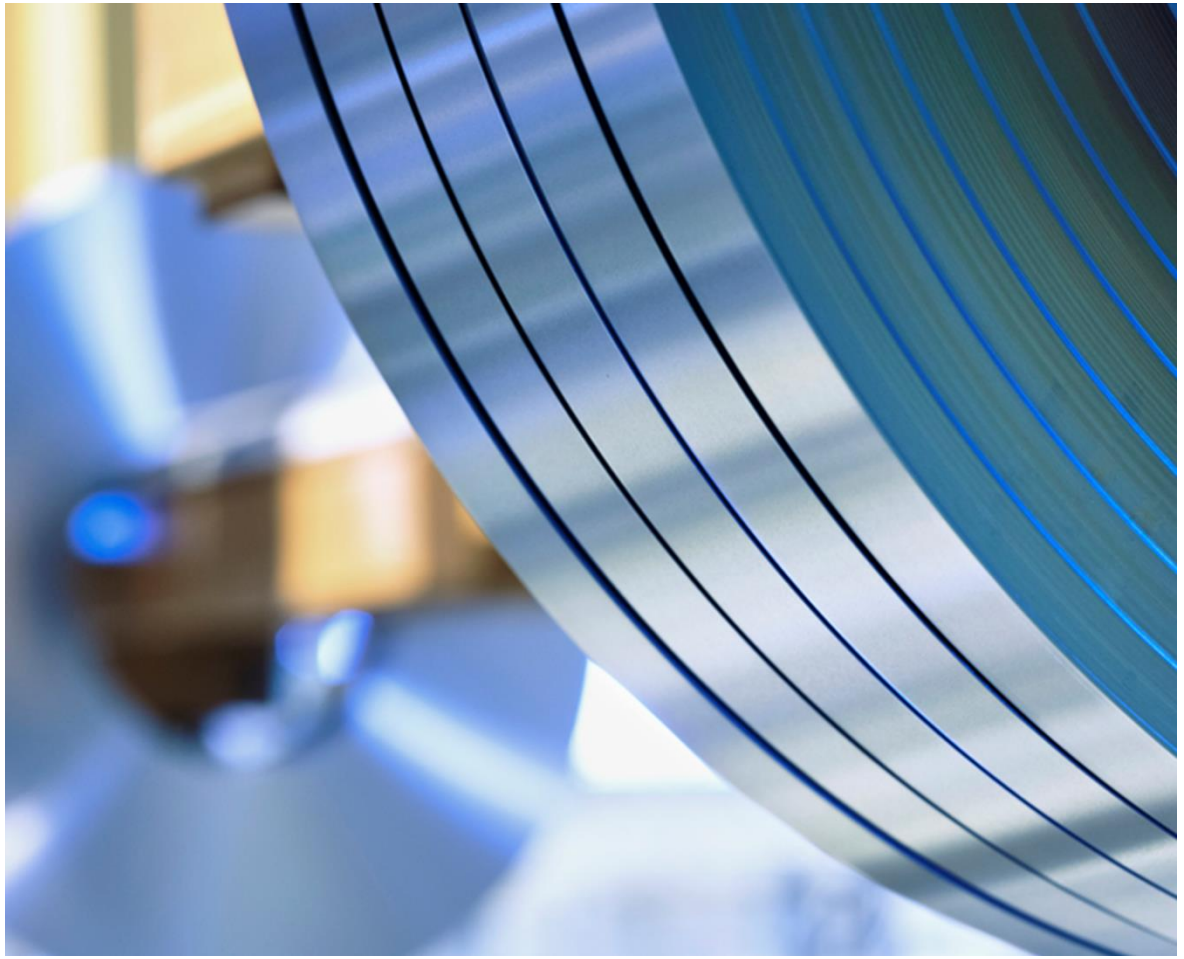
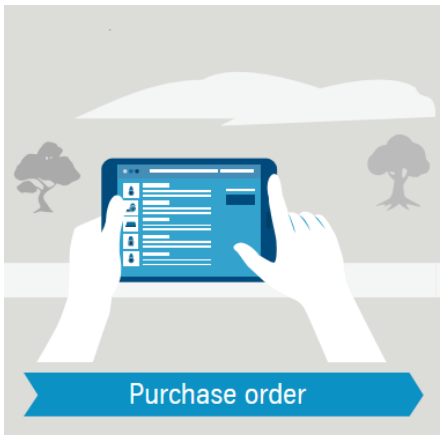


Digitalization at thyssenkrupp Electrical Steel

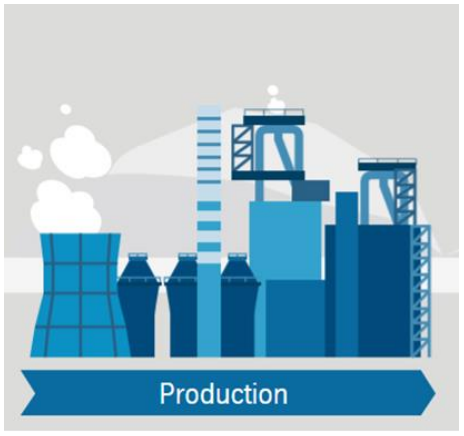
Transparency via SteelOnline platform

https://online.thyssenkrupp-steel.com/

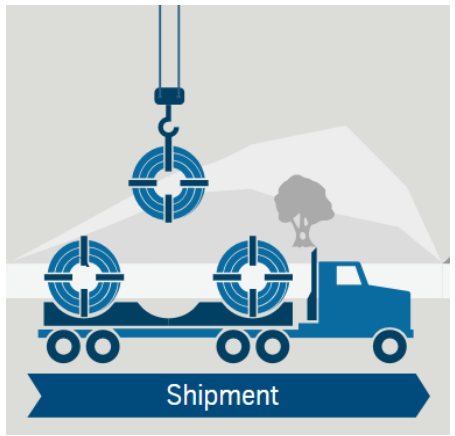
Sale of stock material
via e-auction



- Sale of stock material
- Sales of IA-Material



Order status and progress



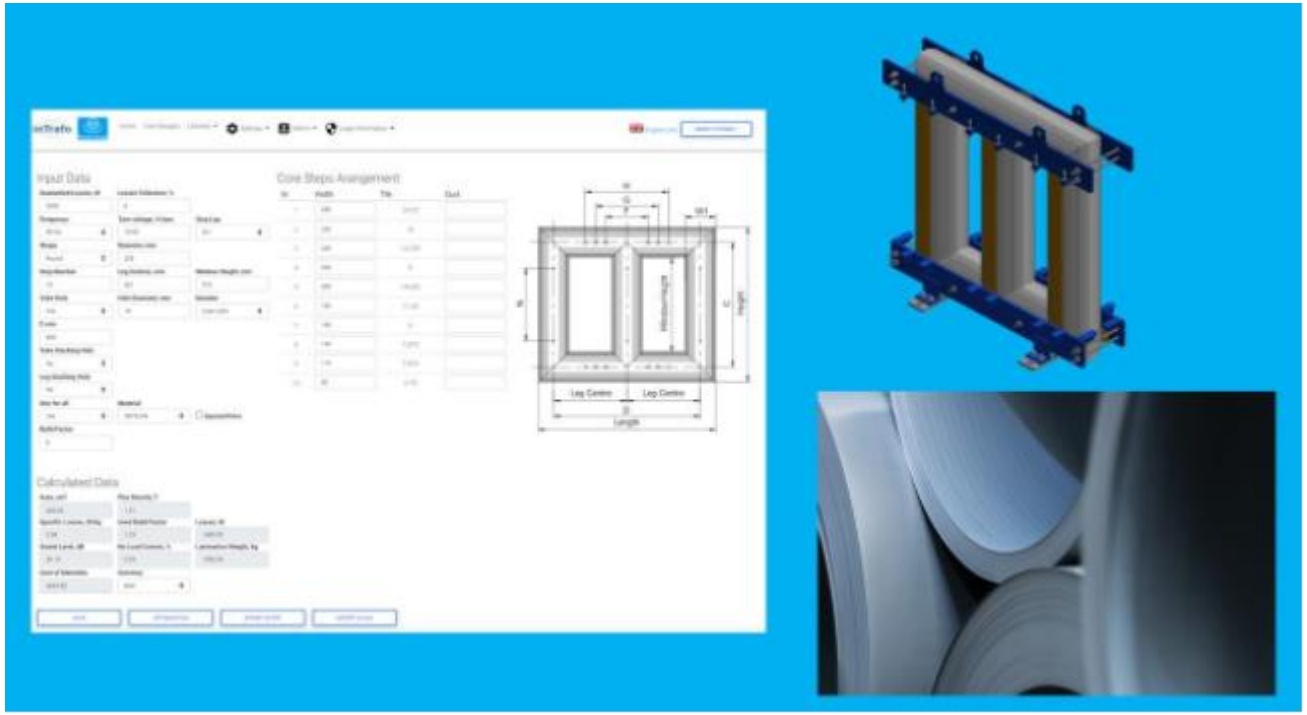
- Material ready for shipment
- Documents: delivery notes, invoices, order confirmation, certificates

More than 90 customers out of 72 companies from 24 different countries are already activated as users

The portal is available in English, German, French, Spanish & Italian language

inTrafo-Software – smart calculation of transformer cores

- One step beyond in digitalization and innovation at thyssenkrupp Electrical Steel.
- All our customers now have free access to our new software solution:
  we ease the way of designing and optimizing transformer cores.
- The inTrafo – Core software helps to calculate various types of transformer cores in a very efficient way – it allows to use different thyssenkrupp Electrical Steel grain oriented electrical steel grades within the same core.
- The result is the best and most cost efficient core material combination to achieve desired no load losses.
- The creation of this cost-efficient design and optimization of transformer cores is in line with IEC standards and global efficiency regulations.

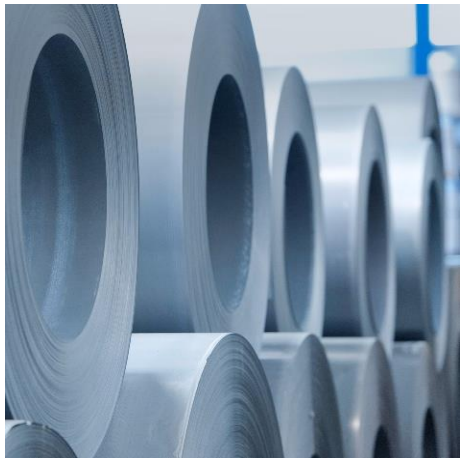


Efficient material usage – handling of GOES and its impact on transformer properties

The transformer no-load loss not only depends on “pure” magnetic properties of GOES.
Also handling (incl. slitting and stacking) and core geometry (i.e. flux distribution) affect the efficiency of the device.

$$W_{core} = P_{sheet} \times m_{core} \times BF$$

W_{core}	No-load loss measured at fully assembled core
P_{sheet}	Specific magnetic loss of GOES sheet (e.g. P17 on MTC for full-width properties)
m_{core}	Weight of the core
BF	Building Factor (≥ 1)



Mother Coils
BF = 1.00

Slit Coils
BF ≈ 1.03-1.07

Stacked Core
BF ≈ 1.15-1.30

inTrafo Transformer Go Green

- The worldwide increasing demand for electricity is a major cause of rising CO2 emissions in the world.
- Adding more transformers to the power system increase the CO2 emissions from the grid.
- Carbon footprint calculation available in inTrafo software is the powerful tool for transformers manufacturers and utilities for strategic planning and design.
- inTrafo software is able to calculate CO2 emission during production phase and lifecycle for a transformer and support CO2 reduction of Scope 3 direct & indirect

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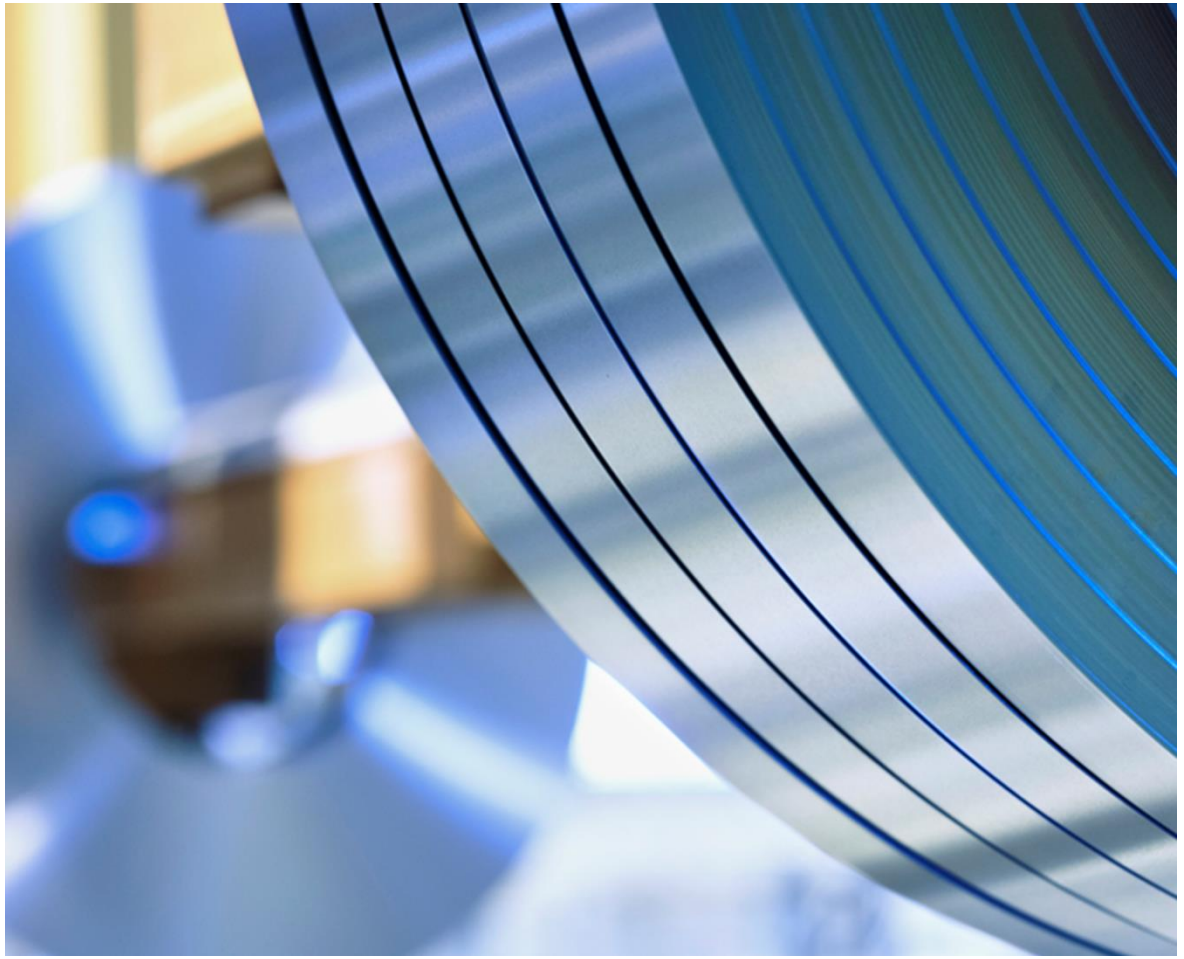


Green transformation

Challenges and opportunities

~ 419 kg
Steel per capita & year

~ 5 %
CO_2 share steel

~ 7 %
CO_2 share steel

~ 2.5 %
CO_2 share tk in D

~ 25 %
CO_2 share tk in the Ruhr region

2030

6 m t CO_2 saving

Conversion of 3 million cars to electric propulsion

tkSE requirement: ~ 14 TWh 2030

Corresponds to 120 % of the electricity demand of the city of Hamburg

H_2

Best exchange rate

1 t H_2 saves 26 t CO_2

Our goal by 2030

>30 %

Reduction in CO_2 emissions (-6 m metric tons)

Our goal by 2045 at the latest

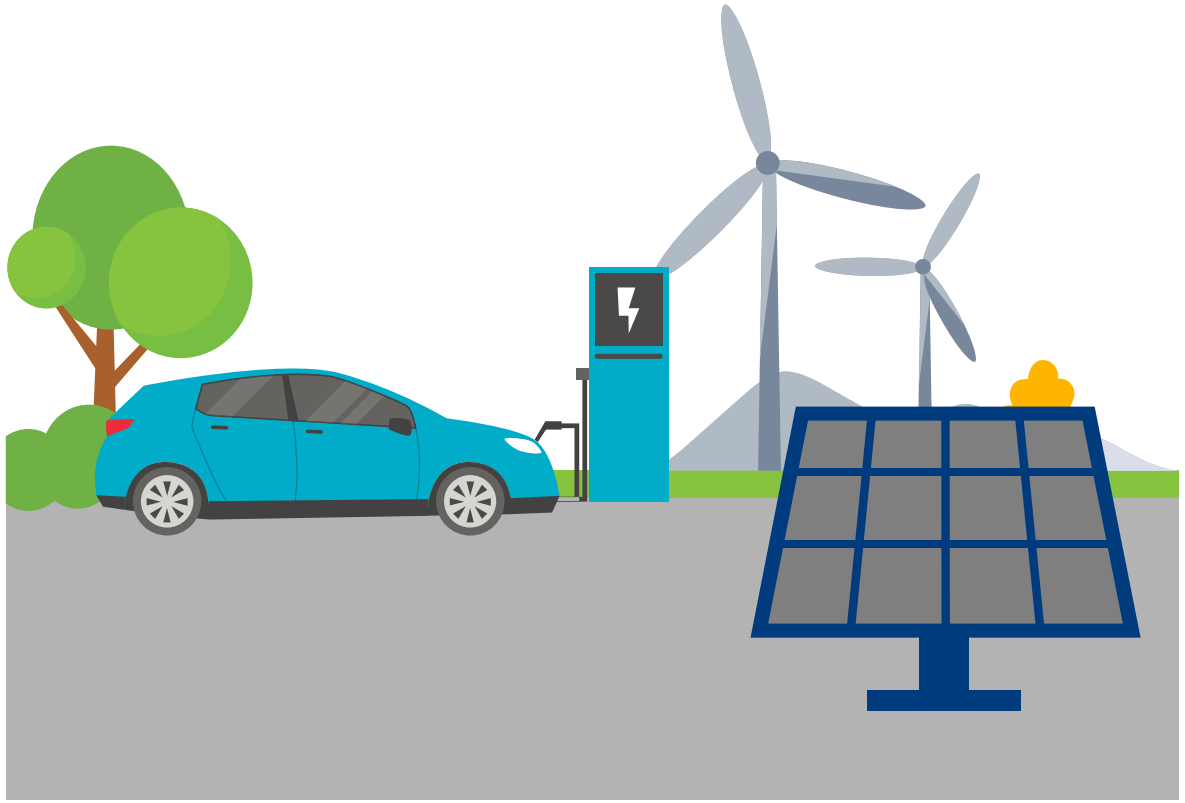
-100 %

CO_2 emissions (-20 m metric tons)

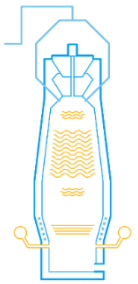
-30% CO_2 emissions in 2030 refers to Scope 1 and Scope 2 emissions (reference year 2018). Additional target by 2030,

Steel is an essential component for a sustainable and successful energy transition …

… which is why we are converting our production to "green" to meet this requirement



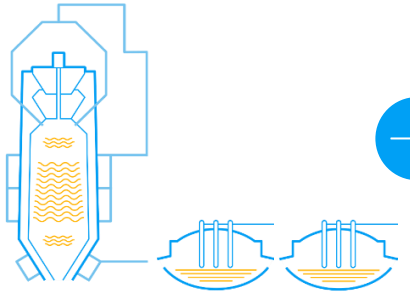
Today



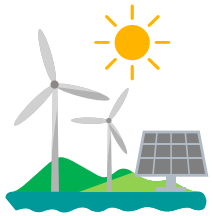
Blast furnace

Iron ore & coking coal

Tomorrow



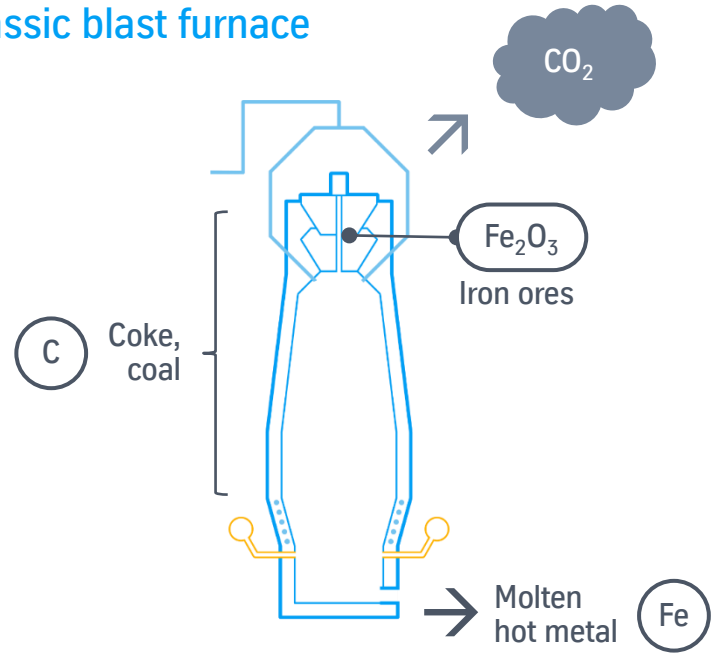
Direct reduction plant with melting units



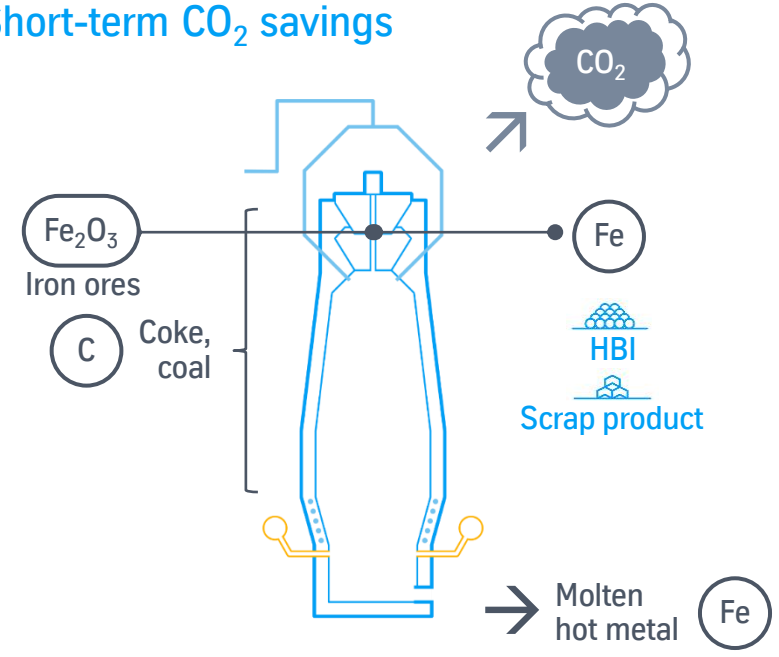
Iron ore, hydrogen & green electricity

Mechanisms of action of the transformation and possibilities for short-term CO_2 savings

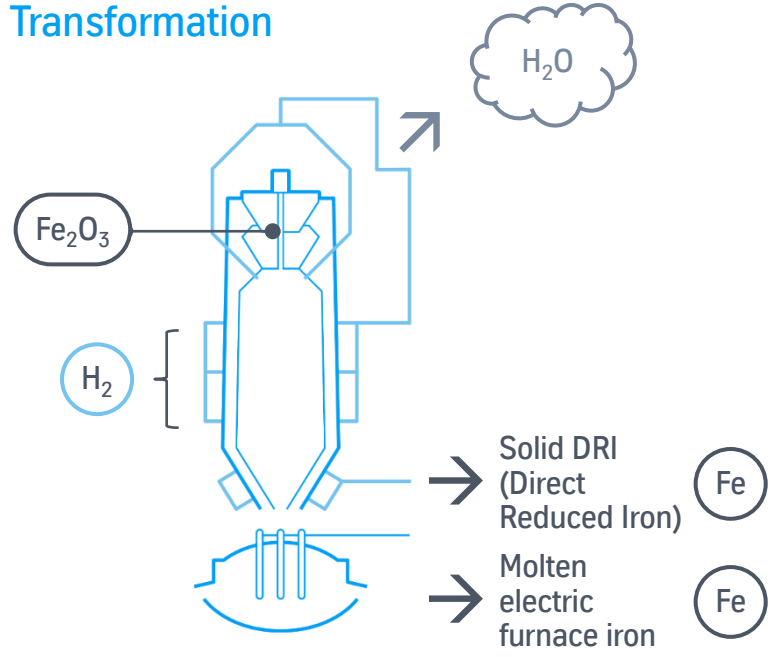
Classic blast furnace



Short-term CO_2 savings



Transformation

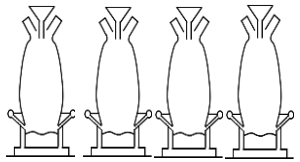
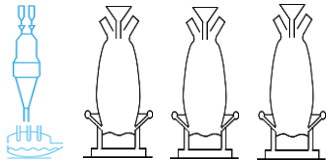
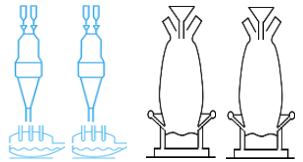
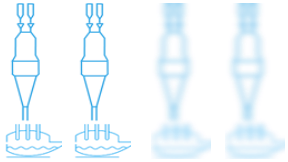


- Carbon as a reducing agent and energy carrier

- Change of input materials in existing processes leads to real CO_2 saving
- Already marketing CO_2-reduced products

- Hydrogen as a reducing agent in the direct reduction plant
- Green electricity as an energy carrier in the melting unit

Green transformation – Clearly defined master plan to reduce CO_2 emissions

up to 2025	from 2026	up to 2030	up to 2045
 Replace blast furnaces with DR plant + melting unit →			
CO_2 saving: 2 %	20 %	> 30 %	100 %
Output bluemint® Steel: 50 – 500 kt/a	~ 3 m t/a[1]	~ 5 m t/a[1]	11.5 m t/a[1]

Advantages – tkH_2Steel technology

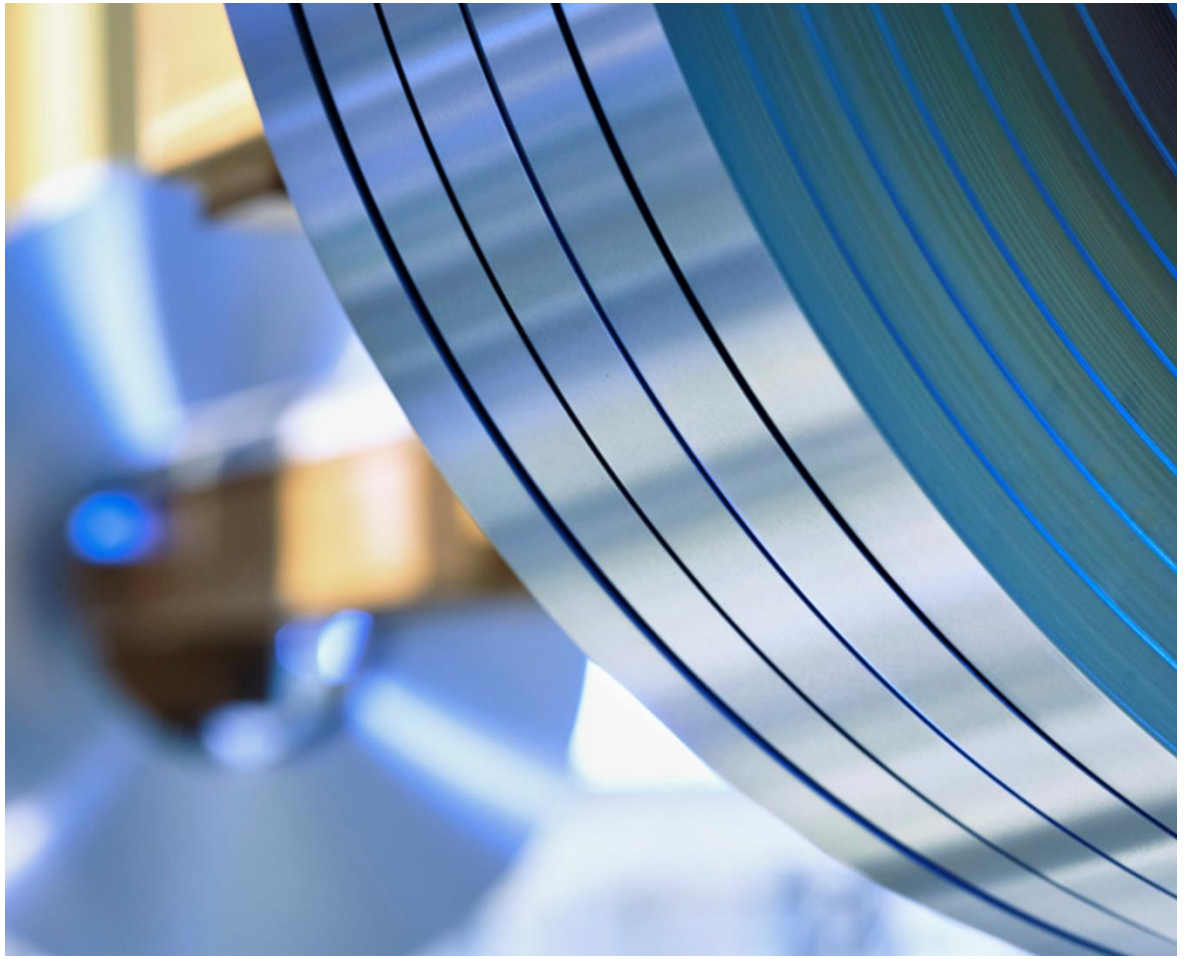
- Innovation Leadership
- Energy efficiency ("hot-link")
- Complete portfolio of grades
- No change downstream

Advantages – Duisburg

- Best European location for steel
- Outstanding infrastructure
- System-relevant
- Financing options

1. Quantity after plant ramp-up

Agenda



bluemint® Steel

Artificial word with meaning

bluemint® Steel

The **blue** symbolizes the power of nature, purity and our climate.

mint stands for fresh and new, formative for our future.

bluemint® homepage: https://www.thyssenkrupp-steel.com/de/produkte/bluemint/bluemint.html

bluemint® pure and bluemint® recycled products support you in improving your carbon footprint – credibly and reliably

Balance-sheet approach requires clear CO_2 savings

- Balance-sheet approaches do not conflict with LCA standards[1] – analogous to how green electricity is handled
- Physical connection between the production route and bluemint® products – no compensation

- Only dedicated, additional CO_2 savings measures are taken into account
- No deterioration in the CO_2 value of conventional products
- Achieved CO_2 savings are externally audited and certified

CO_2 saving with certificate

bluemint® pure

Allocation of CO_2 savings in the overall process to the bluemint® quantities

bluemint® recycled

Mass balancing via a scrap product route in the blast furnace process

1. DIN EN ISO 14067, GHG protocol

bluemint® pure and bluemint® recycled

Plenty of quality, less CO_2

Genuine CO_2 saving through changes in blast furnace charge materials

Certified accounting approach allows allocation of CO_2 savings to a product

Complete portfolio of grades can be produced with the usual high quality

bluemint® pure

Use of hot briquetted iron (HBI) in the blast furnace
Use of biomethane as a natural gas substitute and prospects for H_2 use in the blast furnace

1.5 t CO_2 (70 %)

GHG Protocol for Product Accounting, DNV

Carbon intensity of 0.6 t CO_2/t hot strip

Measure

CO_2 saving

External certification

Carbon footprint of conventional steel 2.1 t CO_2/t hot strip

bluemint® recycled

Use of a specially processed scrap product in the blast furnace

1.35 t CO_2 (64 %)

DIN EN ISO/IEC 17029 TÜV SÜD VERIsteel standard

Spec. CO_2 emissions of 0.75 t CO_2/t hot strip

"Zero emissions" does not mean "zero"

Company searches for carbon credits

- More and more companies are claiming to produce zero emissions products

Technically not feasible

- Steel production is not possible without carbon for purely physical reasons

Transparency and credibility

- Calculating “zero” emissions is achieved by overbalancing or compensating
- Mass-balancing for technically feasible products is to be preferred

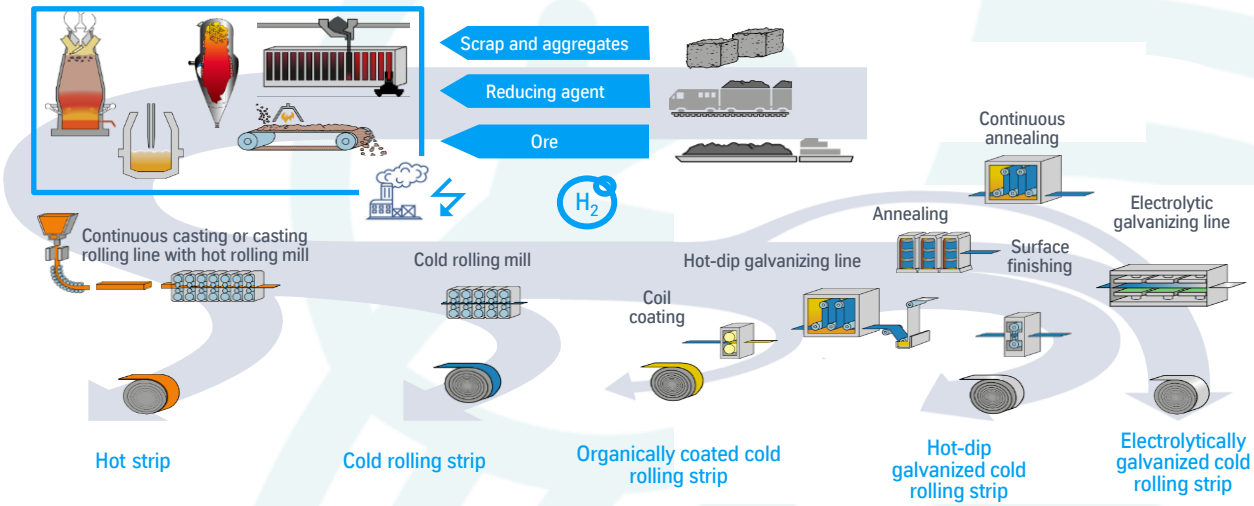
“zero emissions” claim not credible

bluemint® Steel reflects real CO_2 savings applicable to all flat steel produced at tkSE

CO_2 footprint, in t CO_2e/t

Conventional steel	bluemint® recycled	CO_2 savings from bluemint® recycled
Hot strip		
2.10	0.75	64%
Hot-dip galvanized		
2.37	0.95	60%
NO electrical steel		
2.75	1.13	59%
GO electrical steel		
3.80	1.9	50%

All relevant production steps are taken into account in our detailed life cycle assessment model for our integrated iron and steel plant



Certification of the genuine CO_2 savings by TÜV Süd

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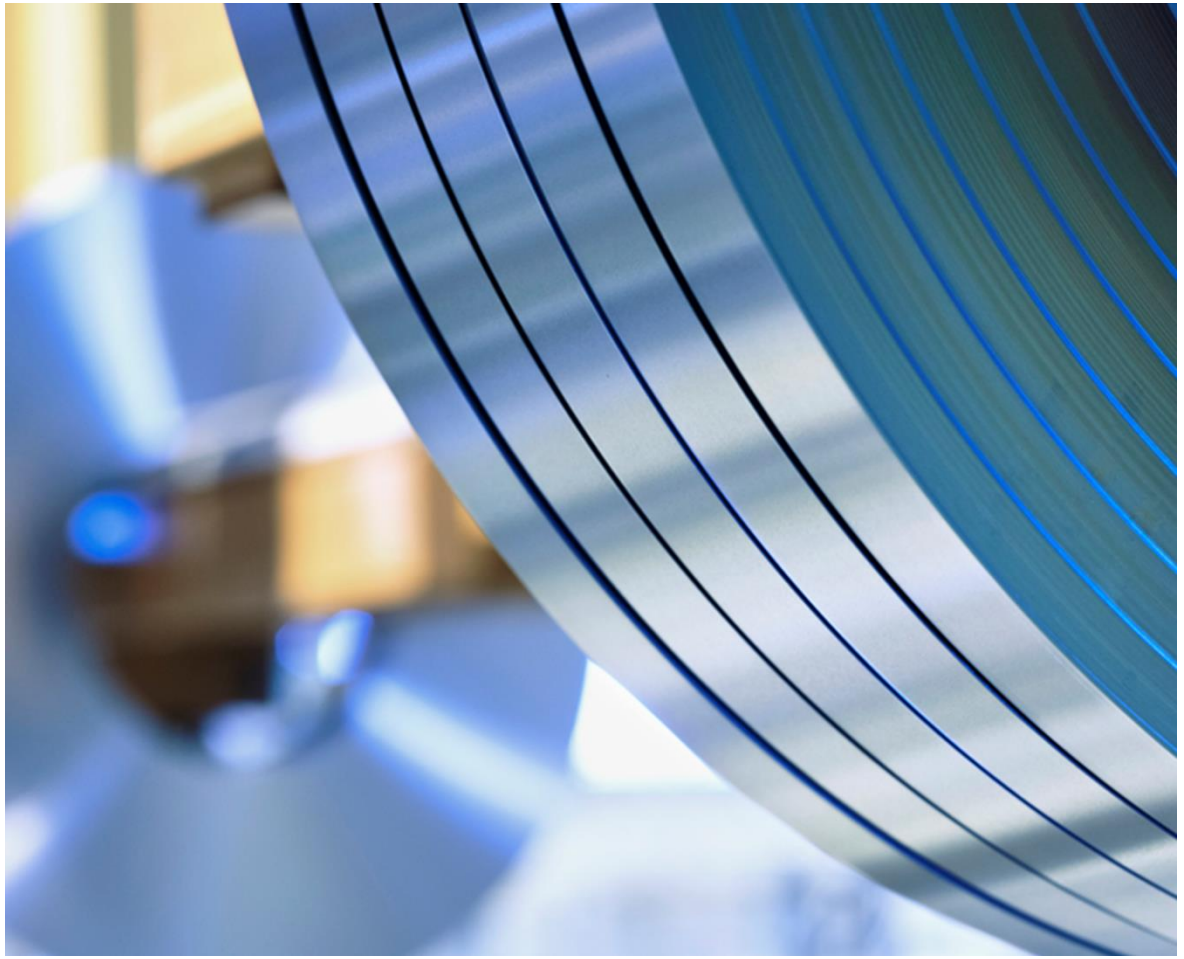
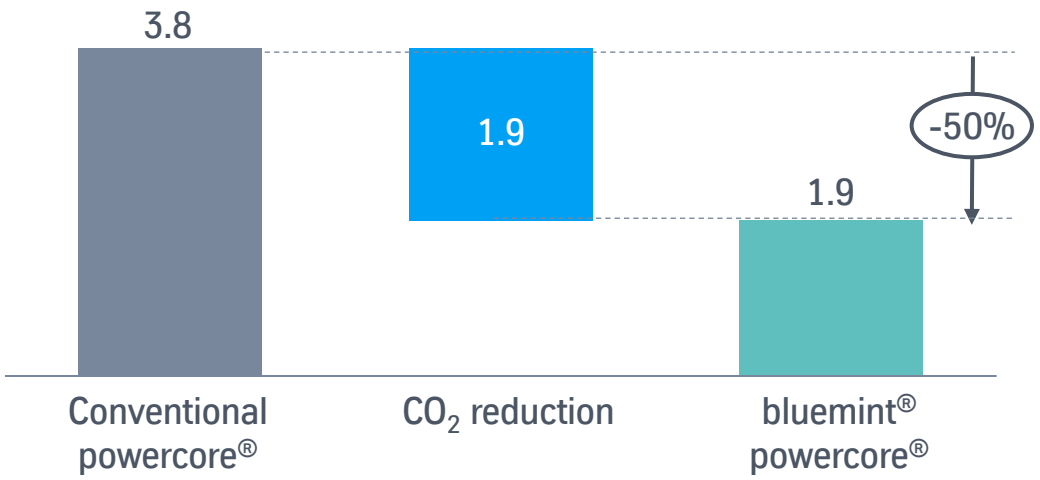


bluemint® powercore® provides you with numerous advantages and opportunites to reduce upstream emissions along the supply chain

CO_2 intensity in grain oriented electrical steel
(t CO_2-equ/t powercore®)



Effortless technical implementation

Continuation of existing processes means there is no need for (re-) qualification

Continuous commitment to excellent magnetic and low-noise performance

What is a green transformer ?

- Low CO_2 footprint during transformer lifetime

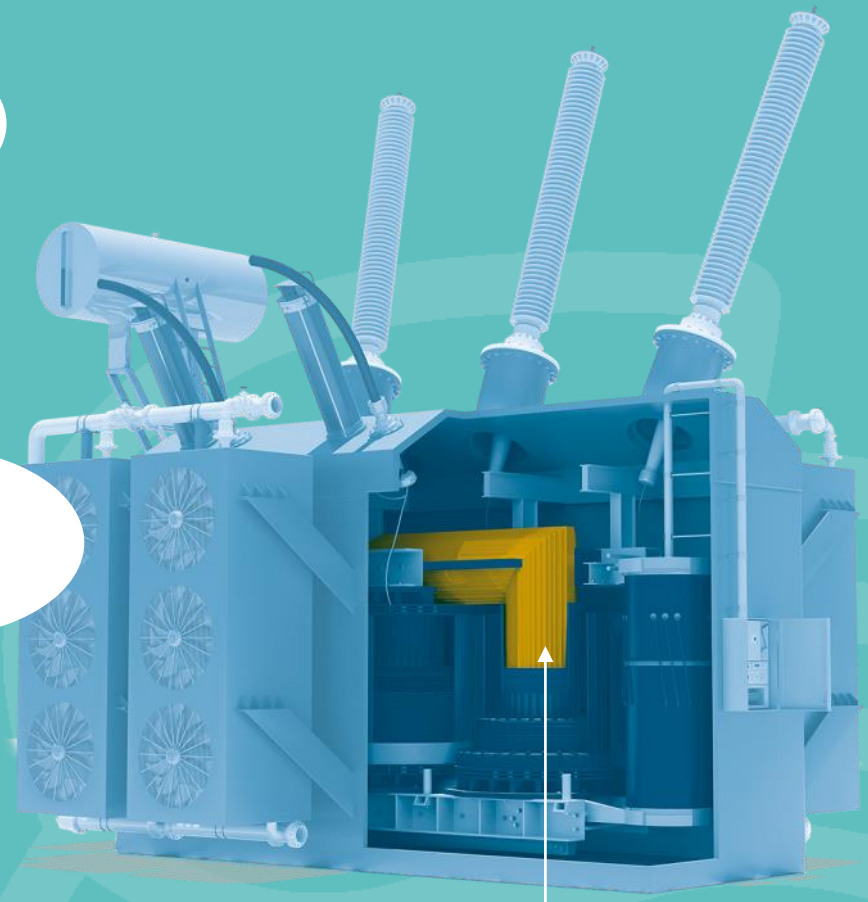
scope 3
indirect

➔ reduced no-load loss by using GOES TOP grade
leading to reduced CO2 scope 3 emissions over life time

- Low CO_2 footprint of used transformer components:

scope 3
direct

➔ Grain oriented steel with a reduced CO2 emission factor
leading to a reduced CO2 emission for the production phase



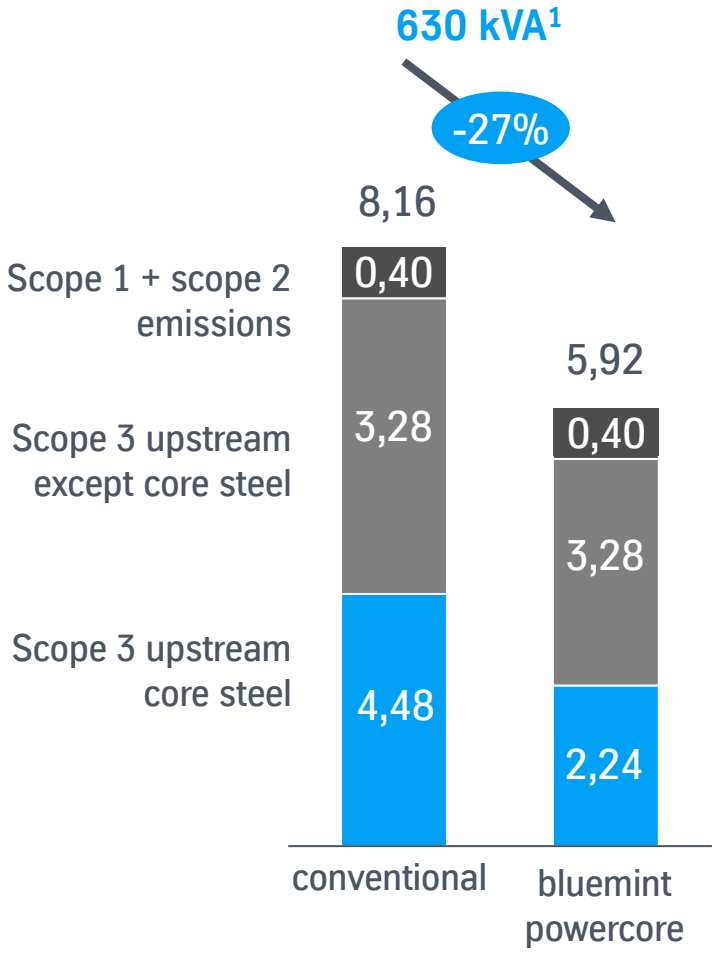
powercore®
Grain Oriented Electrical Steel

thyssenkrupp Electric Steel GmbH in partnership with inTrafo S.r.l.

bluemint® Powercore ® in your transformer reduce Scope 3 direct upstream CO2 footprint up to 30%

With inTrafo core software we have access to all materials produced at thyssenkrupp Electrical Steel and we can design optimal transformer based on losses and materials cost to fulfill latest regulations and save CO2 emission & ownership cost

Transformer emissions during production phase (in t CO_2)



Transformer costs and smart design will contribute to better performance during life cycle (30 years)

Design	No Load Losses, P_0	Load Losses, P_{sc}	Total transformer cost	Total weight, kg	Dimensions		
	W	W			Length	Width	Height
Traditional design - C120 - 27 (M4) - losses CkEo	1300	6500	5.733,50 €	1.760	1.425	930	1.560
Low losses design - H085 - losses Tier 1	600	6500	7.115,98 €	1.950	1.405	925	1.670
Low losses design - H075 (BLUE MINT) - losses Tier 2	540	4600	9.569,85 €	2.370	1.200	955	1.780
Low losses design - H080 - Tier 2	540	4600	9.362,95 €	2.520	1.280	960	1.840
Low losses design - H085 - Tier 2	540	4600	9.666,63 €	2.650	1.300	965	1.870

Energy saving by 29%

Smart design: reduced dimensions and weight

According to latest EU regulation as Tier 2 EcoDesign

Top grades by tkES lead to cost benefits and CO_2 reduction

scope 3
indirect

bluemint® Steel

Cost comparison: 630 kVA transformer acc. to CkEo, Tier 1, Tier 2 calculated by intrafo-software

Higher transformer costs made by H075-23 bluemint compensated by higher efficiency during operational time

After 30 years cost advantage of around 50 %

Electricity price: F1: 362 €cent/kWh, F2 & F3: 262 €cent/kWh | yearly price increase 2% | 37,5 % price gap between C120-27 and H075-23 bluemint

Top grades by tkES lead to cost benefits and CO_2 reduction

scope 3
indirect

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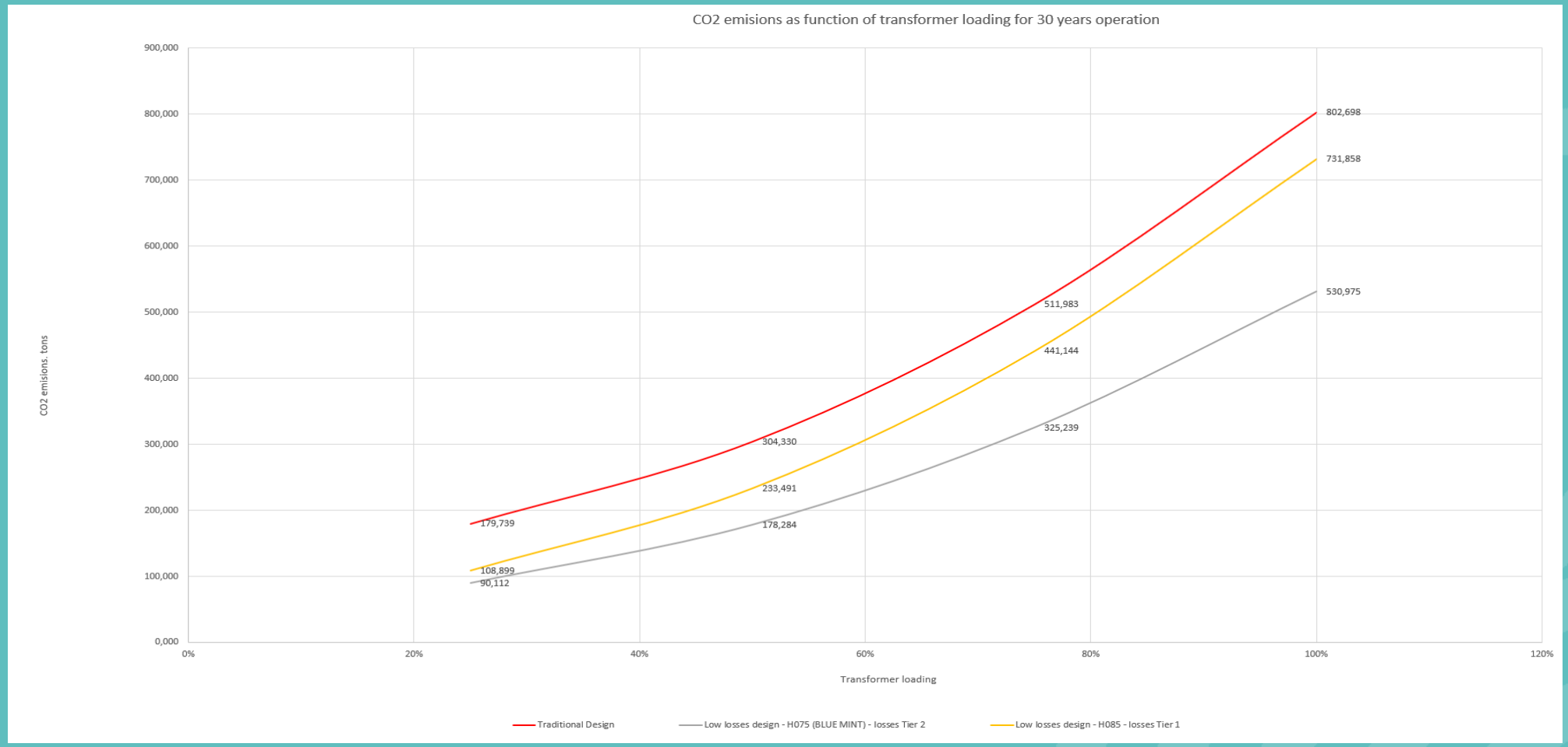
Cost comparison: 630 kVA transformer acc. to CkEo, Tier 1, Tier 2 calculated by intrafo-software

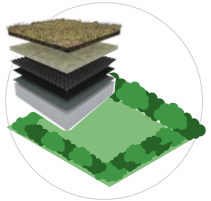


Decrease Scope 3 Indirect up to 33% over life cycle (30 years)

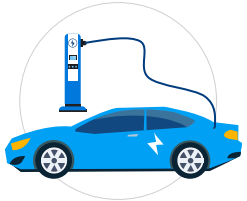
240 t CO_2 can be reduced by ...

bluemint® is a major lever for reducing CO_2 emissions

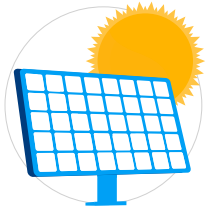
Switching ~9,600 light bulbs to LED



Greening roofs of >790 transformer houses (functioning for 10 years)

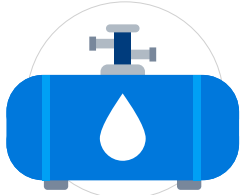


Driving 1.4m km with electric vehicles instead of combustion engines (~36x around the earth)



Installing ~48 solar PV panels operating for 25 years

Replacing ~84 transformers to more energy efficient models



Sourcing ~2.4mn MJ biomethane instead of natural gas (heating ~83 single-family homes for one year)

Producing 1 Power transformer
(126t core weight)
with bluemint® powercore®

Reduction of emissions in purchased transformers is an important part of DSO's strategy

Transformers and Reactors

Low Losses and Biodegradable Insulating liquids (Natural and Synthetic esters)

F. Gasbarri

SUSTAINABILITY
Lower C02 emissions from manufacturing to use

FIRE RESISTANCE
Class K insulating liquid, self-extinguishing

OVERLOADING CAPABILITY/ LIFE EXTENSION
Higher possible operating temperature

BIODEGRADABILITY
Lower environmental impact in case of liquid losses

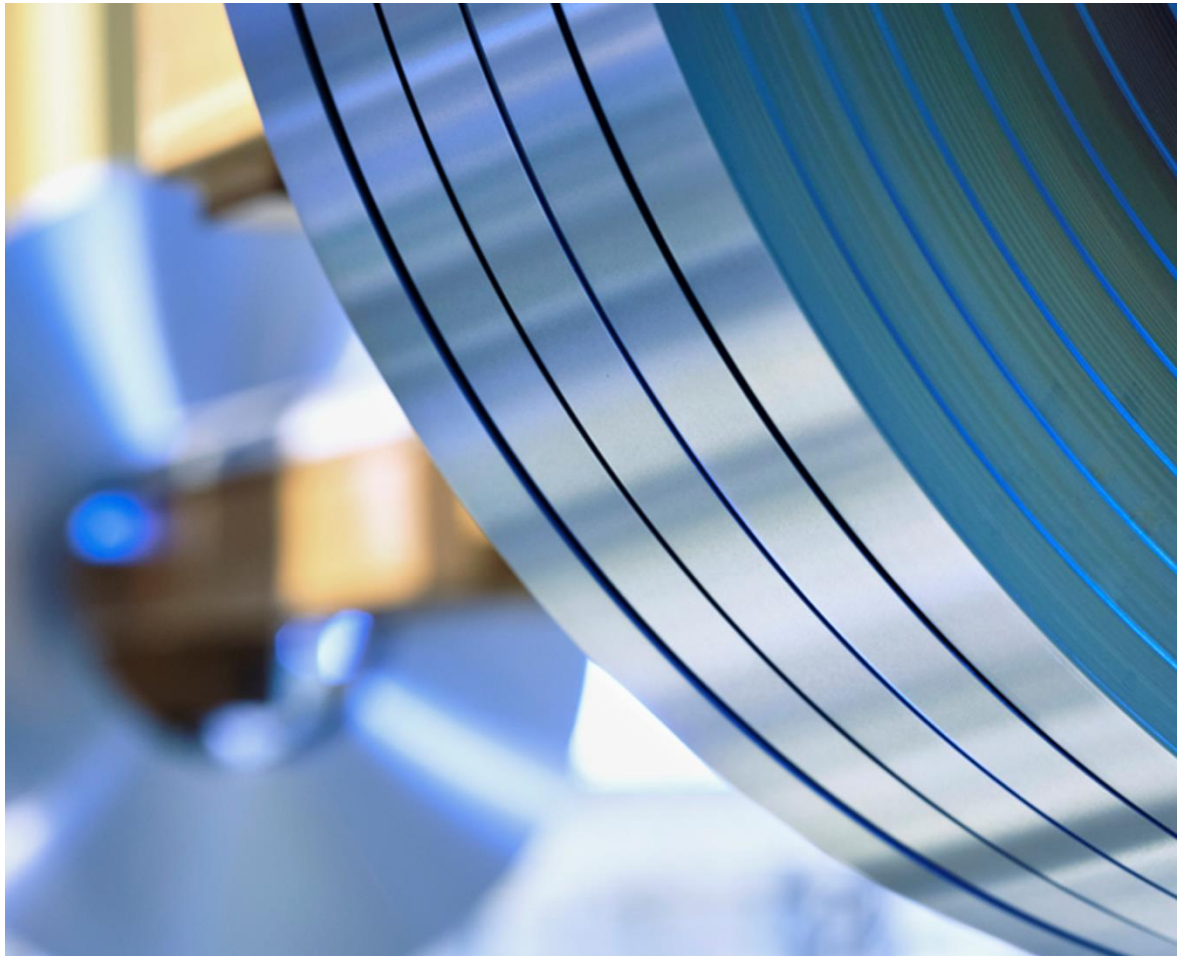
- Enel Global Standards are open to alternative Insulating liquids
- Enel Purchases: 10% of Power Transformers and more than 50 % of Distribution Transformers

Can we optimize the standards for less raw material consumption exploiting natural ester increased performances?

Green steel is an important additional lever to achieve your customers goals for sustainably sourced transformers

Agenda

1. We are thyssenkrupp
2. About thyssenkrupp Electrical Steel
3. Digitalization & innovation
4. Green Transformation at thyssenkrupp Steel Europe
5. Bluemint® Steel – Solution for energy business
6. Bluemint® Powercore® core base for Green Transformer
7. Circular economy leverage & conclusion



Realising the potential of circularity has long been a priority for the transformer industry…

All parts that can be recycled economically are already reused in the global transformers industry

Other parts are entered in the scrap cycle and all raw materials reused for transformers and other products

… but direct recycling of transformer parts is unviable due to efficiency constraints

40+ Transformers have a typical lifetime of 40+ years

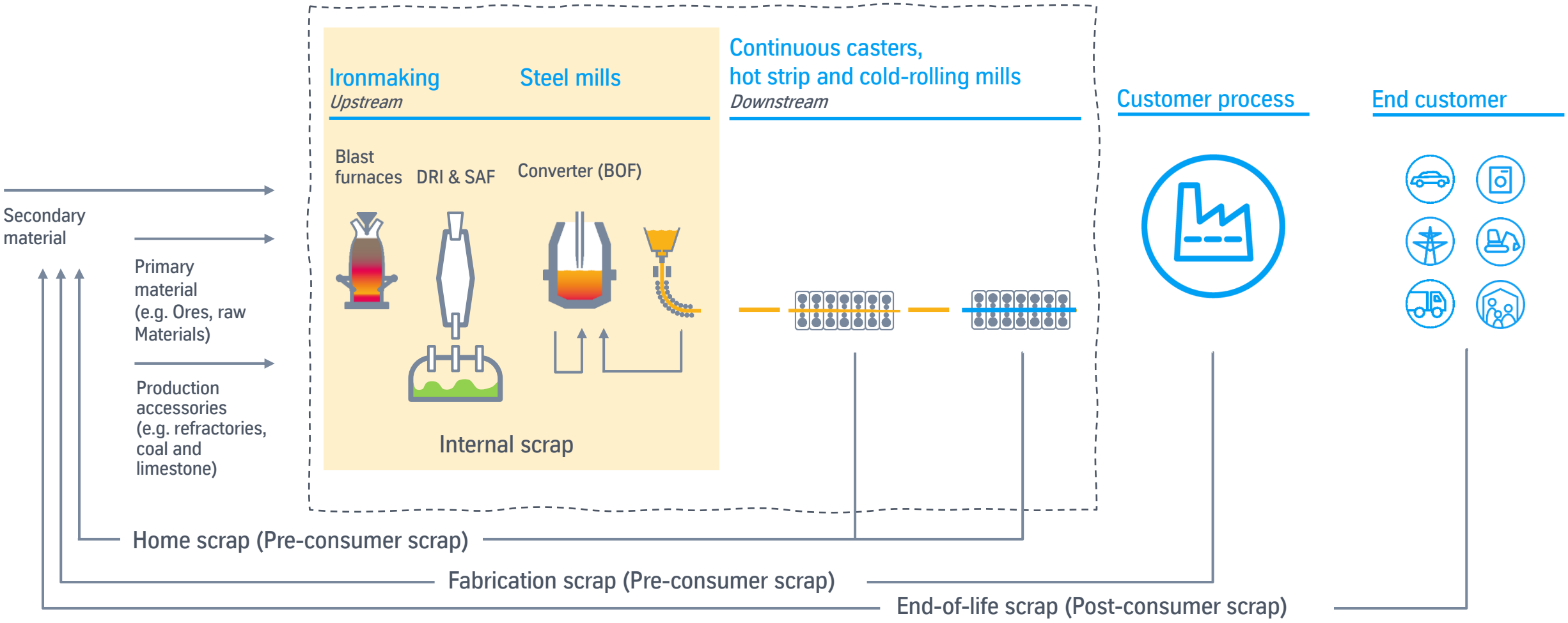
Significant efficiency advancements have been made due to eco-design approaches in the past decades

Re-used parts do not realize this potential and are hence not competitive in terms of efficiency

tkES is ready to develop circularity solutions and closed loops with you!

Scrap input to our steelmaking process

Defined according to ISO 20915:2018



ISO 20915:2018: Life cycle inventory calculation methodology for steel products

bluemint® powercore® supports the decarbonization of the energy industry

What we know

1. To achieve the **goals of the Paris Agreement,** all industries must **accelerate decarbonization**

1.5°
Limitation of global warming

2050
Climate neutrality reached

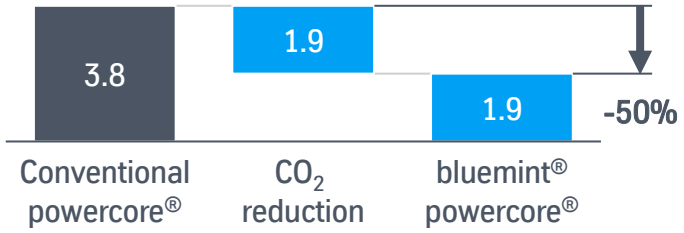
2. **Energy players** are setting ambitious **decarbonization targets**

COMPANIES COMMITTED TO 1.5° TARGET (SELECTIVE EXAMPLES)

SCIENCE BASED TARGETS
e.on · Ørsted · SSE · enel · edp
IBERDROLA · VATTENFALL · TenneT · SIEMENS Gamesa RENEWABLE ENERGY
nationalgridESO · MVV · EWE · EIRGRID

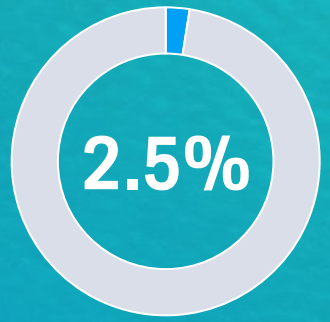
3. **Decarbonized steel**, e.g., **bluemint® powercore®** in the transformer core is a **lever that already exists** today to achieve targets

CO_2 intensity in powercore® (in CO_2/t powercore®)



Our answers

Current share of **tkSE in CO_2 emissions** in Germany



Our target until 2045

-100%
CO_2 emissions **(-20 mn t)**

This translates to…

… 10 mn cars replaced with electric vehicles

… 8 years of domestic flight traffic in Germany

Thank you

for your attention

engineering.tomorrow.together.

thyssenkrupp