

THE ROLE OF BIOMASS IN PRODUCTION OF CEMENT, IRON AND STEEL

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**INTERNATIONAL CENTRE FOR
SUSTAINABLE CARBON**

PRESENTATION OUTLINE

- CO₂ emissions from heavy industry – decarbonisation for net zero trajectory
- Cement manufacture and role of biogenic fuels
- Iron and steel manufacturing – role of carbon
- Carbon science – challenges for drop-in fuel substitutes
- Biomass in iron and steel – RD&D
- Concluding remarks



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Technology Collaboration Programme
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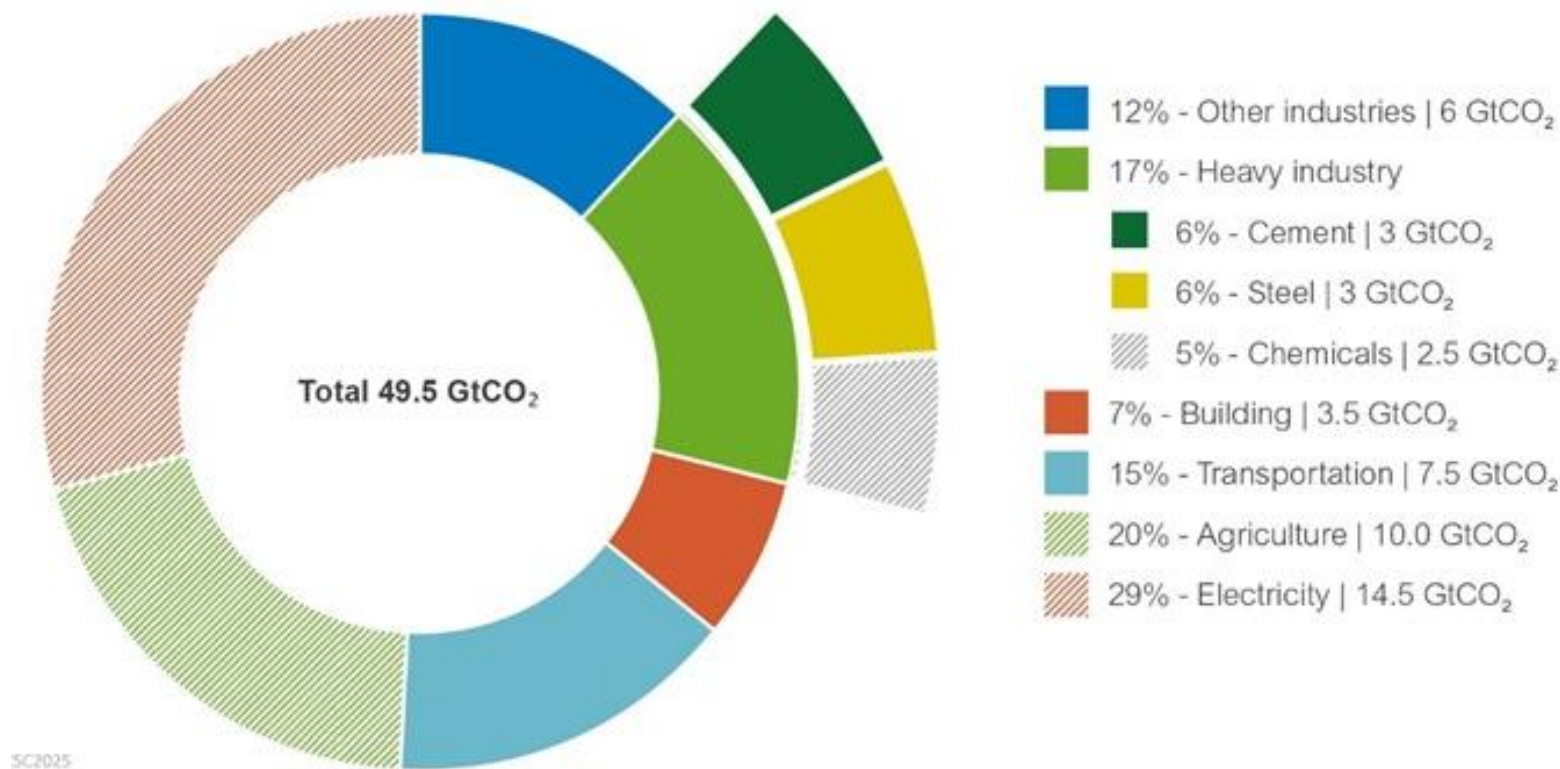
DECARBONISING HEAVY INDUSTRY – NET ZERO PATHWAY





CARBON DIOXIDE EMISSIONS FROM HEAVY INDUSTRY

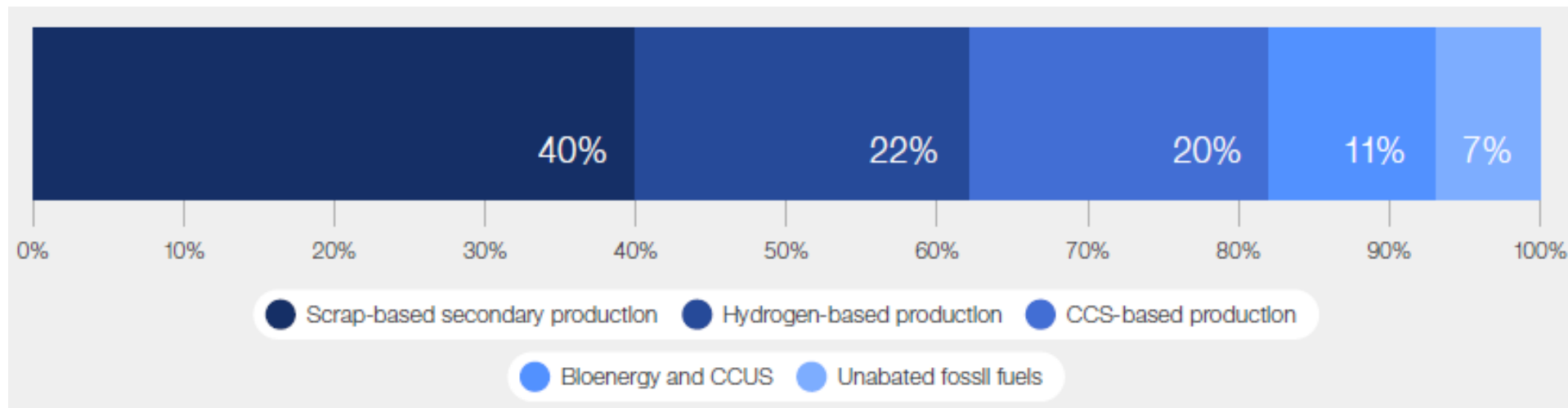
- Total global CO₂ emissions 50.1 Gt (2021), 12% from cement, and I&S manufacture
- Both industries reliant on coal
- Increasing demand for cement and I&S
- Net zero trajectory requires decreased reliance on coal
- Hard to abate sector
- Neither sector is on track for decarbonisation targets
- Regions have different carbon intensities in manufacturing and own roadmaps for decarbonising



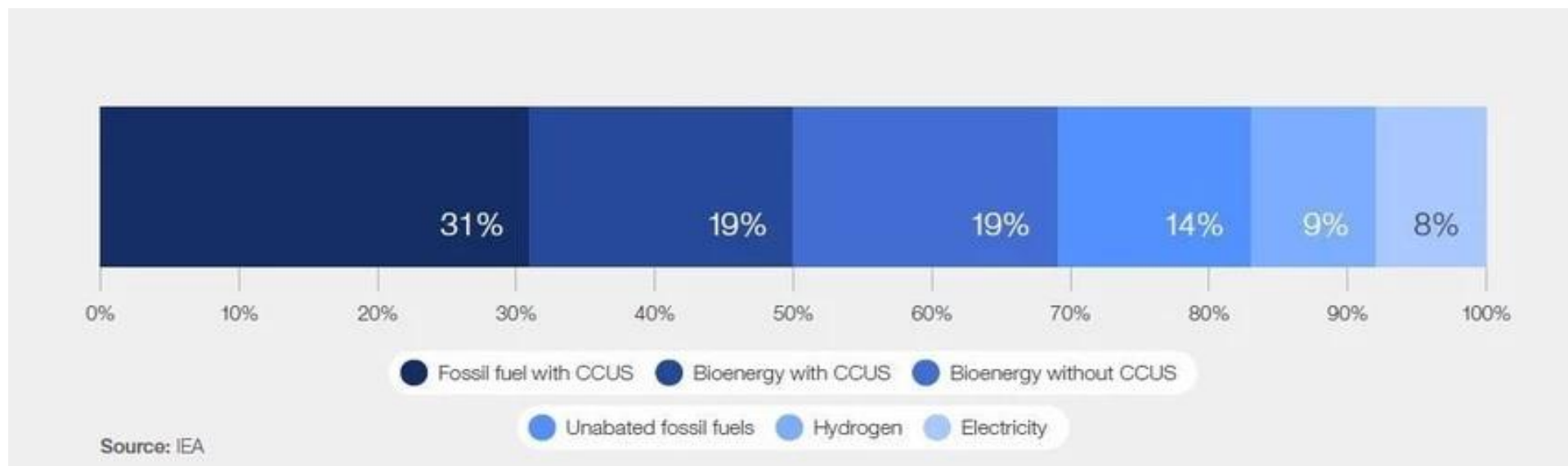
Total global CO₂ emissions by sector, 2021



DECARBONISATION BY 2050



2050 share in
production of **steel**
(World economic
forum, 2023)



2050 share in
production of **cement**
(World economic
forum, 2023)

CEMENT MANUFACTURING

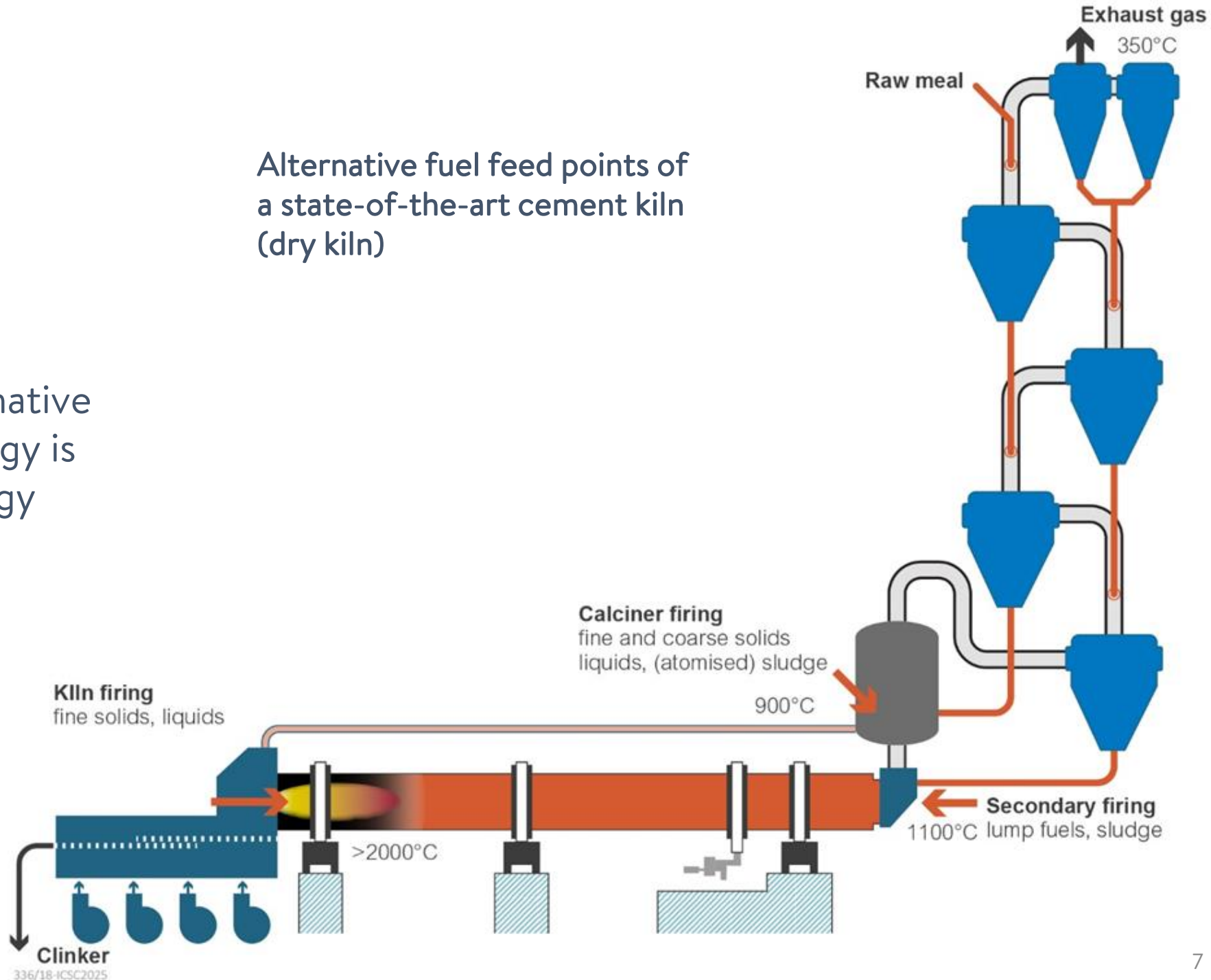




CEMENT

Indicates opportunities for substitution of fossil by alternative biogenic fuels – thermal energy is around 38% of the total energy

Alternative fuel feed points of a state-of-the-art cement kiln (dry kiln)

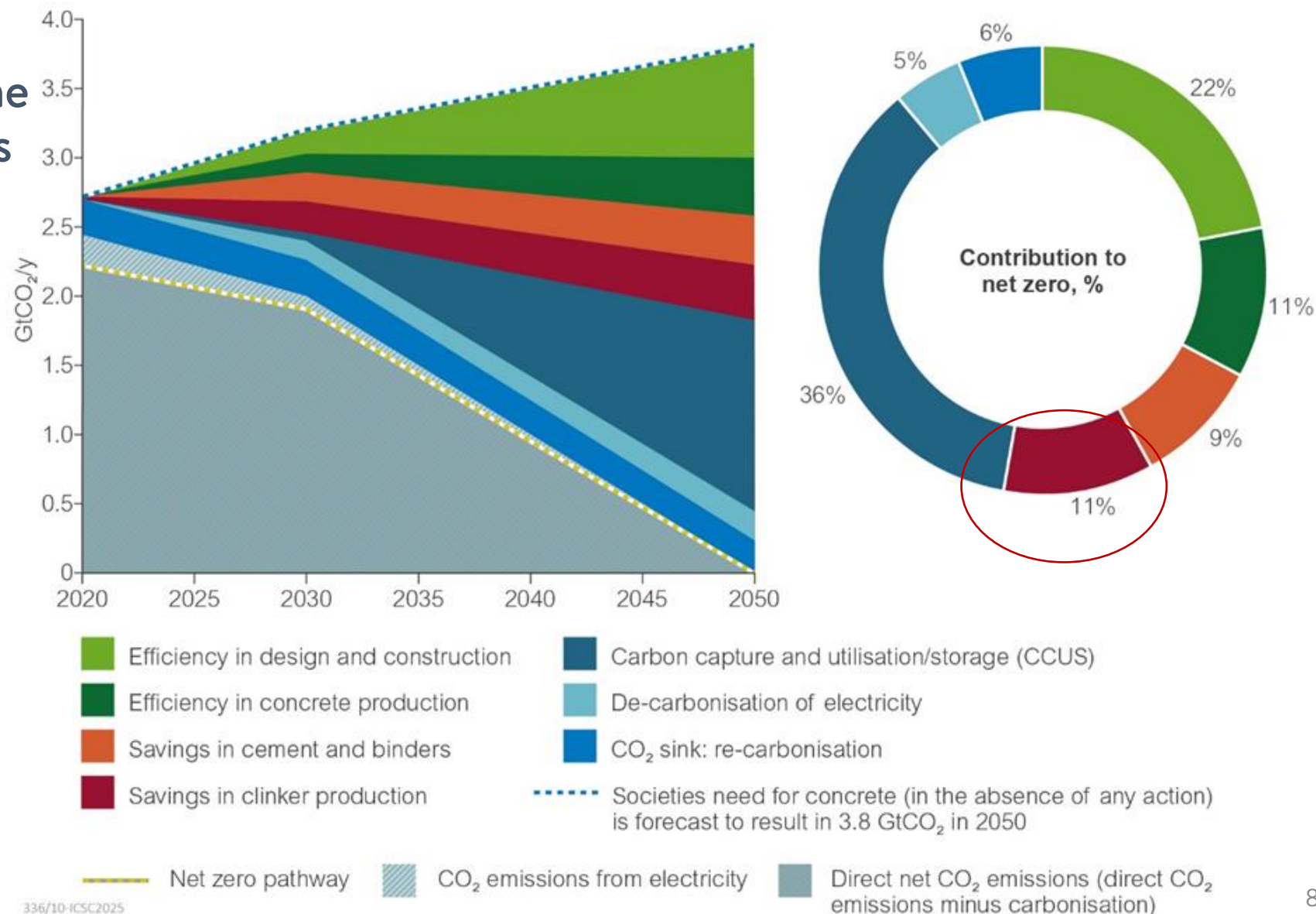




DECARBONISATION ROUTES FOR CEMENT

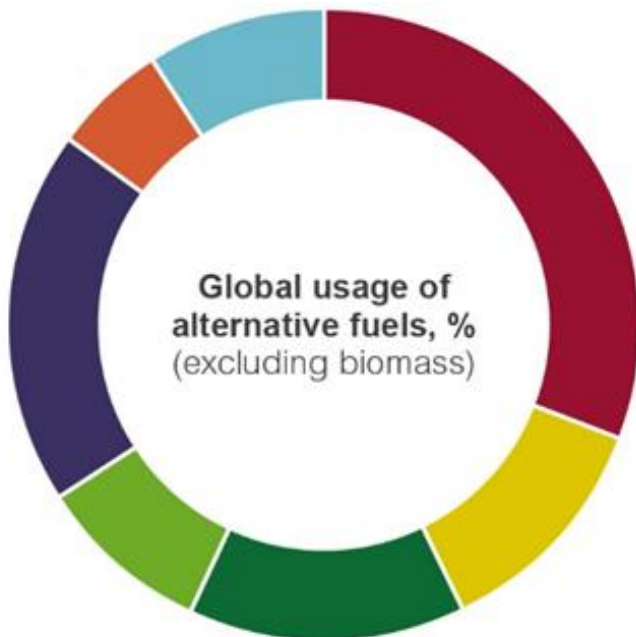
Decarbonisation pathways for the cement industry to meet the global net zero emission targets (GCCA net zero targets)

- Includes fuel substitution
- Alternative fuels, including biogenic sources are being used to displace fossil fuels

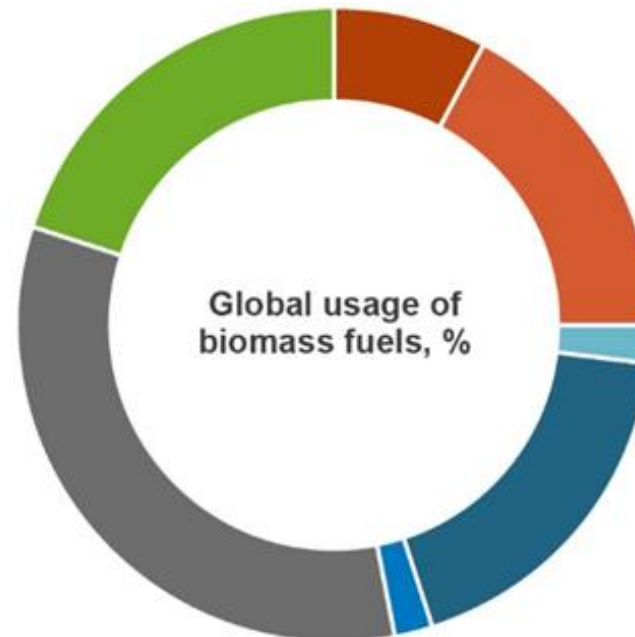




GLOBAL USE OF ALTERNATIVE FUELS (2022)



- 31% - RDF including plastics
- 12% - Other fossil based wastes and mixed fuels
- 14% - Mixed industrial waste
- 9% - Solvents
- 19% - Tyres
- 6% - Waste oil
- 9% - Impregnated saw dust



- 8% - Sewage sludge
- 17% - Wood, non impregnated saw dust
- 2% - Paper carton
- 18% - Animal meat
- 2% - Animal bone meal + animal fat
- 33% - Agricultural, organic, diaper waste, charcoal
- 20% - Other biomass

COMMENTS – CEMENT SECTOR

- Inherent CO₂ emissions (55%) from calcination of calcium carbonate - CCS required
- 38% of total energy from fuel combustion
 - alternative fuels with high biogenic content will displace fossil fuels
- Use of alternative fuels in the calciner and/or kiln, commercial and increasing
 - sewage sludge
 - refuse derived fuels
 - animal meat and bonemeal
 - agricultural and wood wastes
- Fuel composition directly impacts plant emissions and cement quality
- Low CV remains a challenge
- Regional waste management practices affect use

**ALTERNATIVE FUELS INCLUDING BIOMASS
WASTES ARE COMMERCIAL. POTENTIAL TO
REPLACE 100% FOSSIL FUELS FOR PROCESS
HEAT FOR CEMENT MANUFACTURING
PROVIDED REGIONAL SUPPORTING
MECHANISMS ARE IN PLACE.**



IRON AND STEEL MANUFACTURING

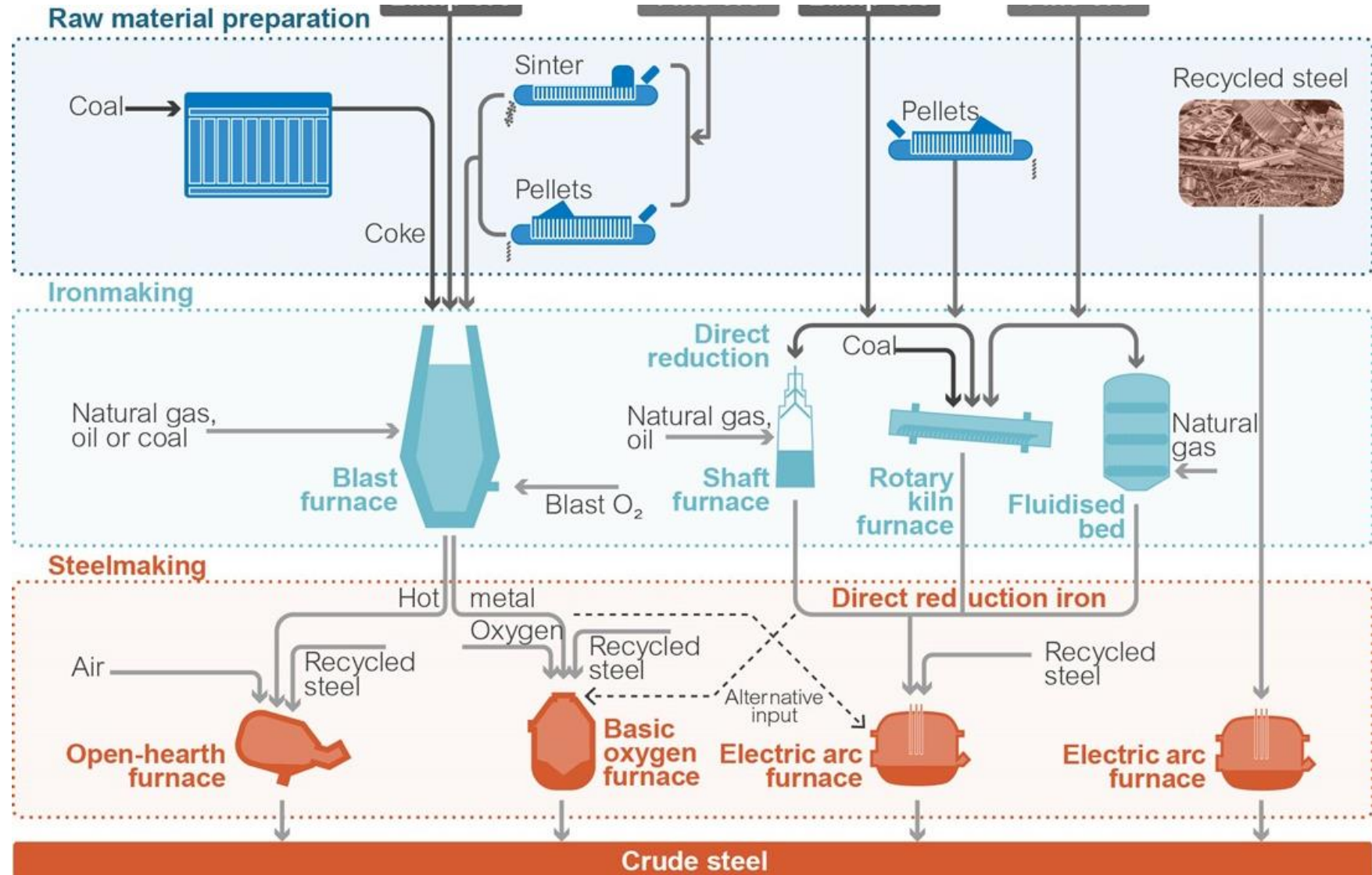




MANUFACTURING ROUTES

Primary steel production methods (Kelsall 2023)

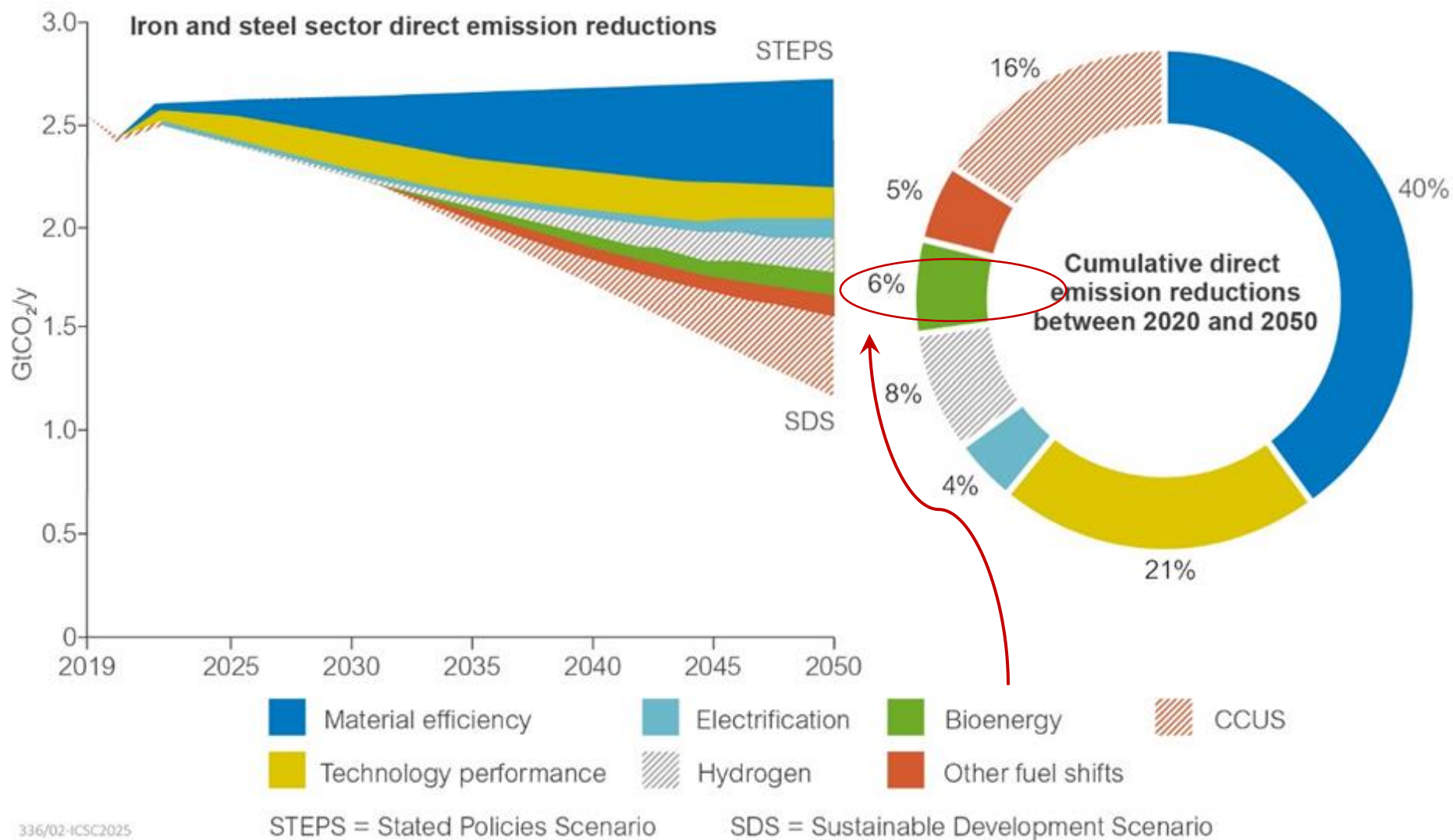
- Coke – high mechanical strength, low reactivity
- Sinter plant: iron ore fines and coke breeze produces agglomerate
- BF (70%) or DRI (25%) reduces iron ore to molten iron
- BOF or EAF convert the molten iron to steel





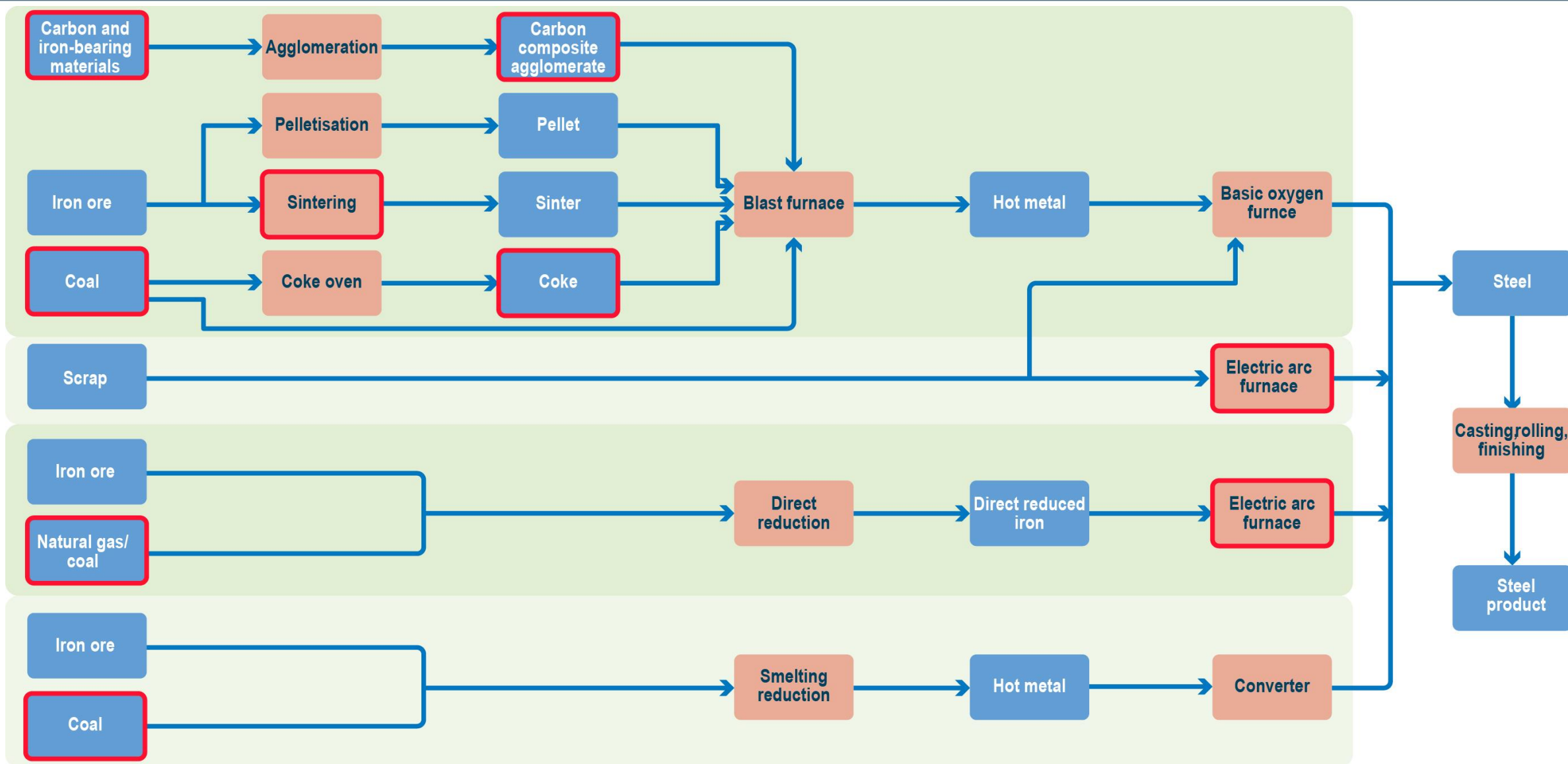
SUSTAINABLE DEVELOPMENT SCENARIOS

DECARBONISATION PATHWAYS FOR THE I&S INDUSTRY ACCORDING TO TWO SCENARIOS





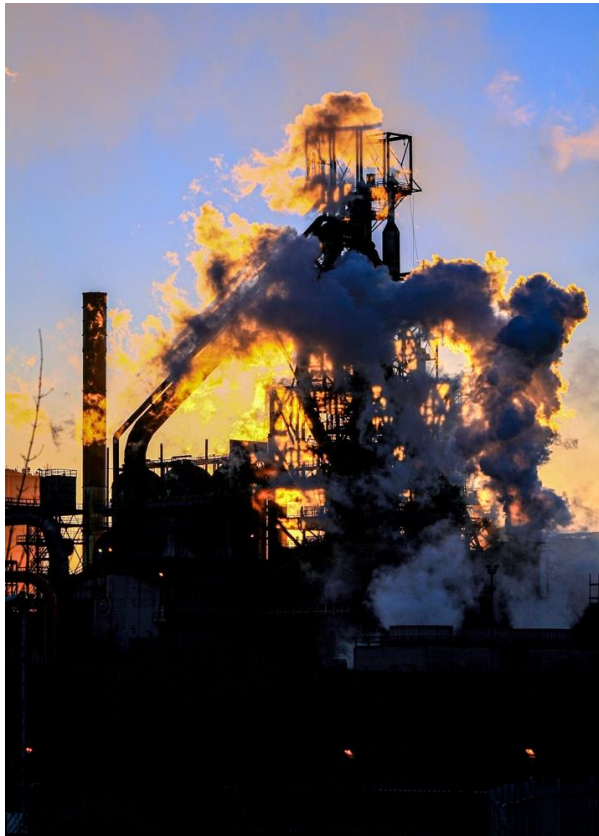
OPPORTUNITIES FOR BIOMASS



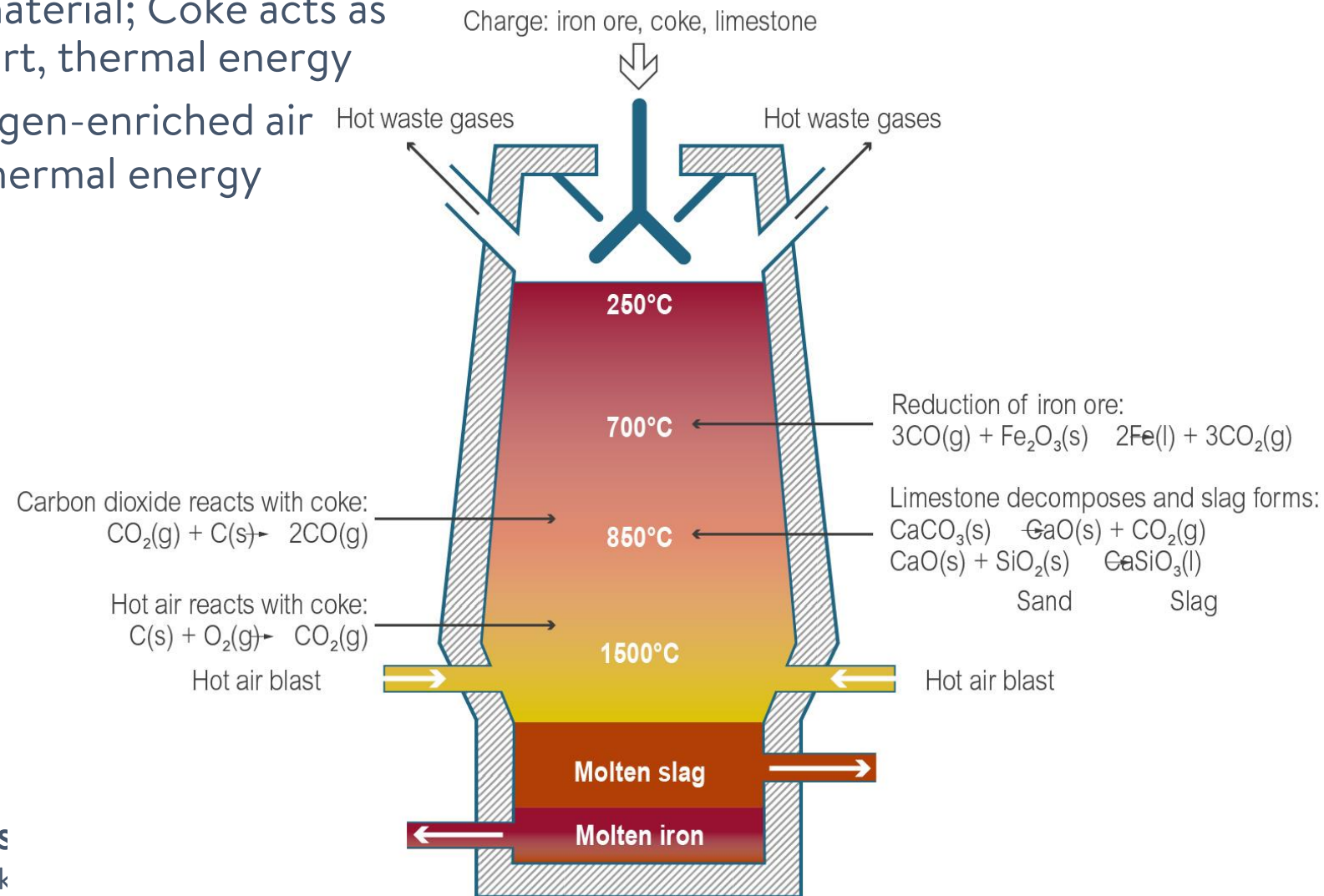


BIOMASS-BASED FUELS/REDUCTANTS IN THE BF

- Carbon introduced in the burden as coke at top of the BF in layers with iron ore, sinter and fluxing material; Coke acts as reductant, permeable mechanical support, thermal energy
- Carbon injected in tuyeres with air/oxygen-enriched air – traditionally pulverised coal. Role – thermal energy



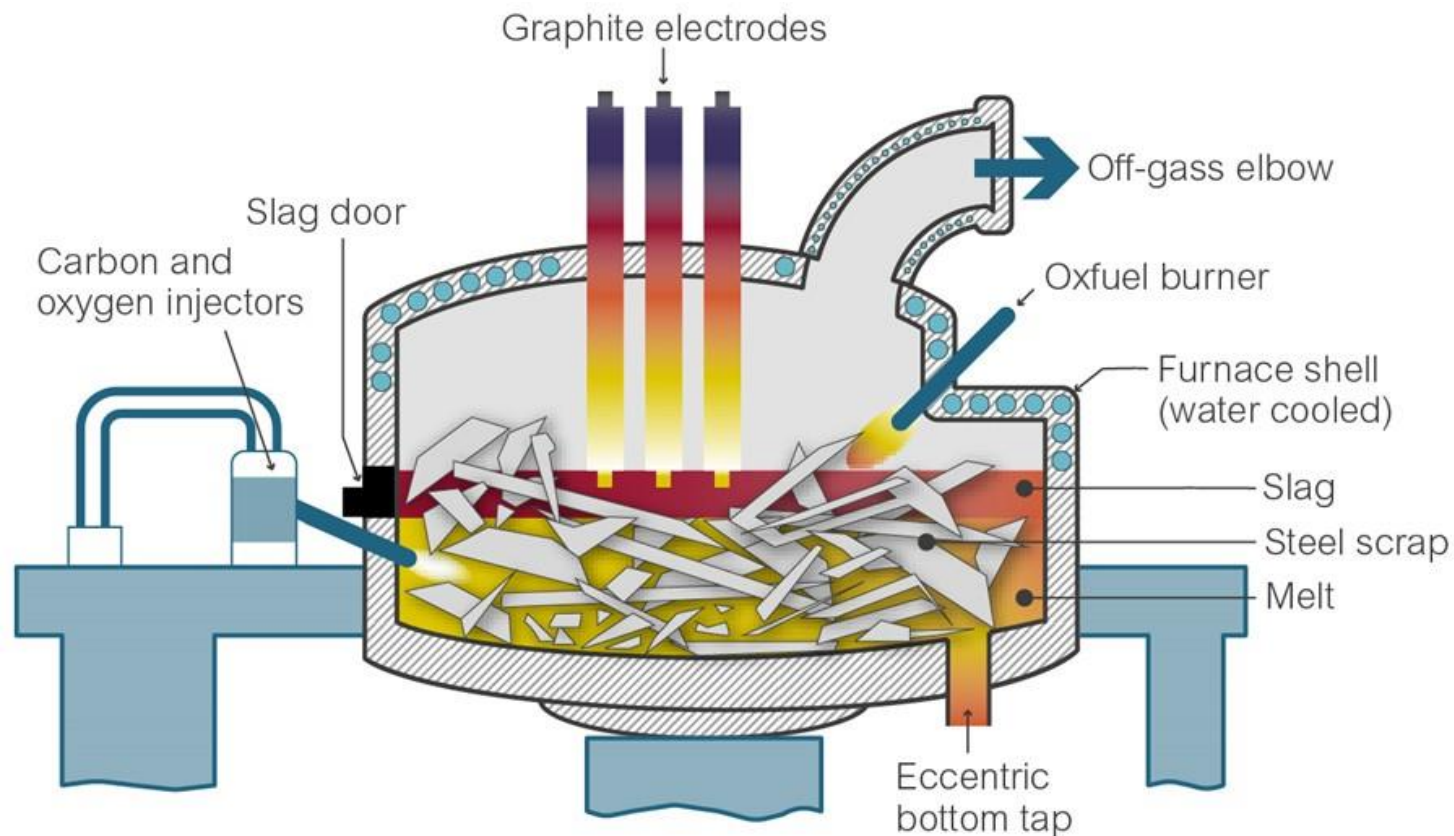
Port Talbot blas
Image: Shutterstock





BIOMASS-BASED FUELS/REDUCTANTS IN THE EAF

- Carbon added with the charge or via the oxyfuel burner lances. Provides thermal energy, releases CO and assists with slag foaming



**BF-BOF AND DRI-EAF DOMINANT IN I&S
MANUFACTURE; BOTH RELY ON COAL AND
COKE. PARTIAL SUBSTITUTION BY BIOMASS IN
COKE MANUFACTURE, SINTERING, DRI, AND
INJECTED AND CHARGE CARBON IN THE BF
AND EAF**



CARBON SCIENCE: CHARCOAL VERSUS COKE





ISOTROPIC VS ANISOTROPIC CARBONS

Biomass



Pinning of planes in random orientation

Slow heating to $>400^{\circ}\text{C}$



Charcoal or biochar



Isotropic, non-graphitising

High porosity, high reactivity, low mechanical strength

Coking coal



Mesophase allows alignment of planes

Slow heating to 1000°C



Metallurgical coke



Anisotropic, graphitising

Low porosity, low reactivity, high mechanical strength



COMPARISON OF SOME KEY PROPERTIES

COMPARISON OF PROPERTIES OF SOME SOLID FUELS				
As received	Coke lump (for blast furnace)	Charcoal (high quality)	Pelleted torrefied wood	Wood pellet
Moisture, wt%	1-5	1-5	1-5	7-10
Fixed carbon, wt%	85-88	85-87	22-35	16-25
Volatile matter, wt%	1.0-1.5	10-12	55-65	75-84
Ash, wt%	8-12	1-3	1-2	0.2-1.0
Bulk density, kg/m ³	400-500	180-240	650-800	550-650
LCV (MJ/kg)	~30	~30	18-24	15-17
CRI	~<23	43-53	high	highest
CSR	~>65	low	low	low
Compressive strength kg/cm ²	130-160	10-80	13-75*	
Typical % yield	75-80	~30	61-84	NA

*After torrefying pellets

CHARCOAL CANNOT BE A DIRECT SUBSTITUTE FOR COKE

**CARBONS CAN BE ANISOTROPIC COKE OR
ISOTROPIC CHARCOAL DEPENDING ON
THE PRECURSOR.**

**THE INHERENT POROSITY AND REACTIVITY
OF CHARCOAL AND BIOCHAR DICTATE
THEIR POSSIBLE USES IN I&S
MANUFACTURE**

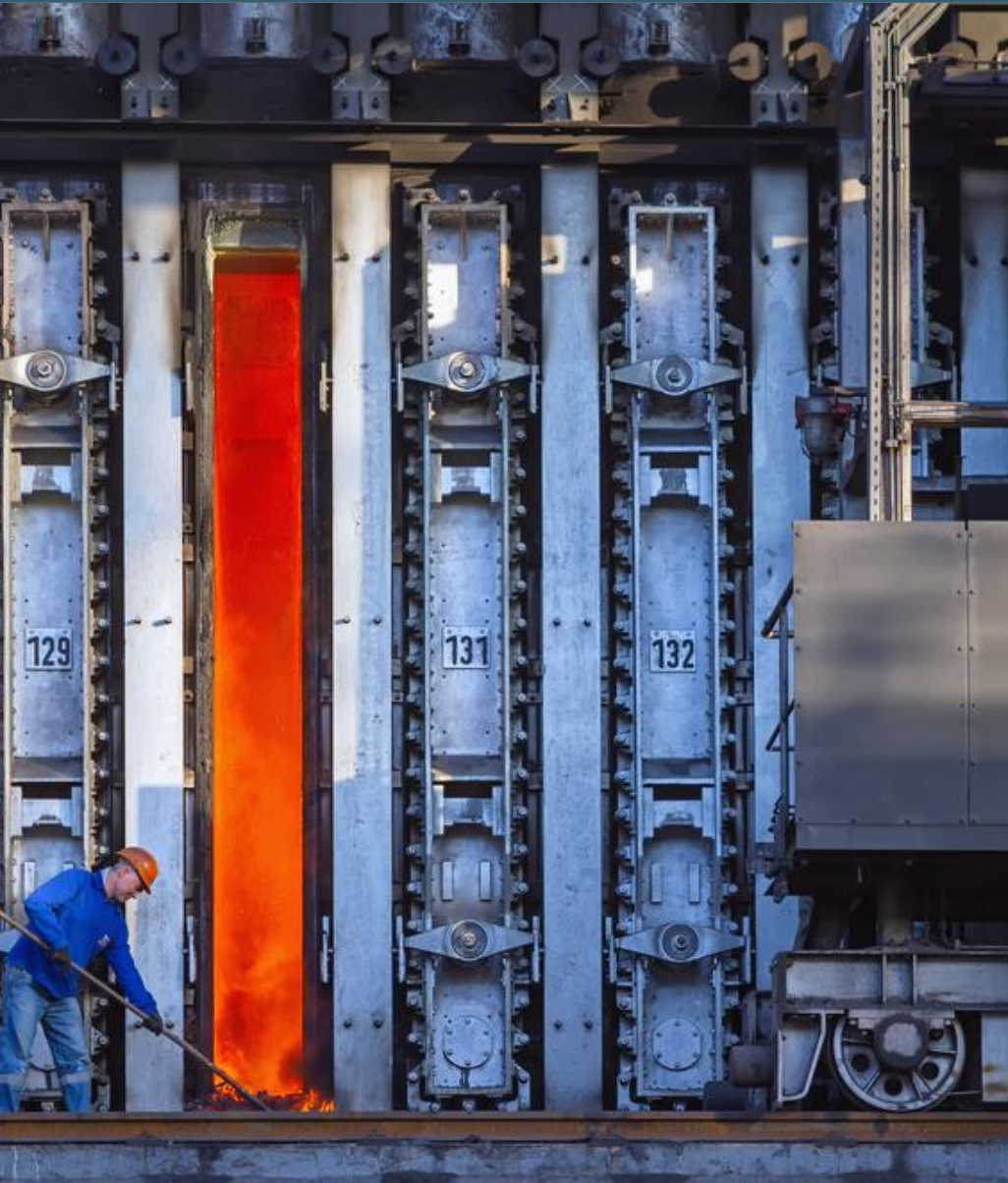


RD&D PROGRESS IN BIOMASS SUBSTITUTION IN IRON AND STEEL MANUFACTURE





BIOMASS AND CHARCOAL IN COKE MANUFACTURING



- Biomass widely studied
- Addition of biomass or charcoal during coke manufacture decreases fluidity. Resultant coke has lower strength and higher reactivity
- 2-10% substitution in the blend (depending on the biomass) delivers acceptable coke properties
- On-going research area

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BIOMASS INJECTION IN BF – R&D

- Small particle size and rapid reaction required
- Pretreated fuels more attractive
- Conveying and injection at high rate - challenge
- Dust explosivity considerations need to be implemented
- Good potential – especially charcoal
- More complete burnout and higher efficiency - lower coke consumption
- High TRL achieved
- High substitution rates possible but limited in practice because of above challenges



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BIOMASS ADDITION IN THE EAF

- Added as either charge or injected carbon
- Higher TRL (3-6) than RD&D in BF

Injected carbon

- Most focus on slag foaming behaviour – not fully understood
- Scaling up from laboratory to large scale – not fully understood

Charge carbon

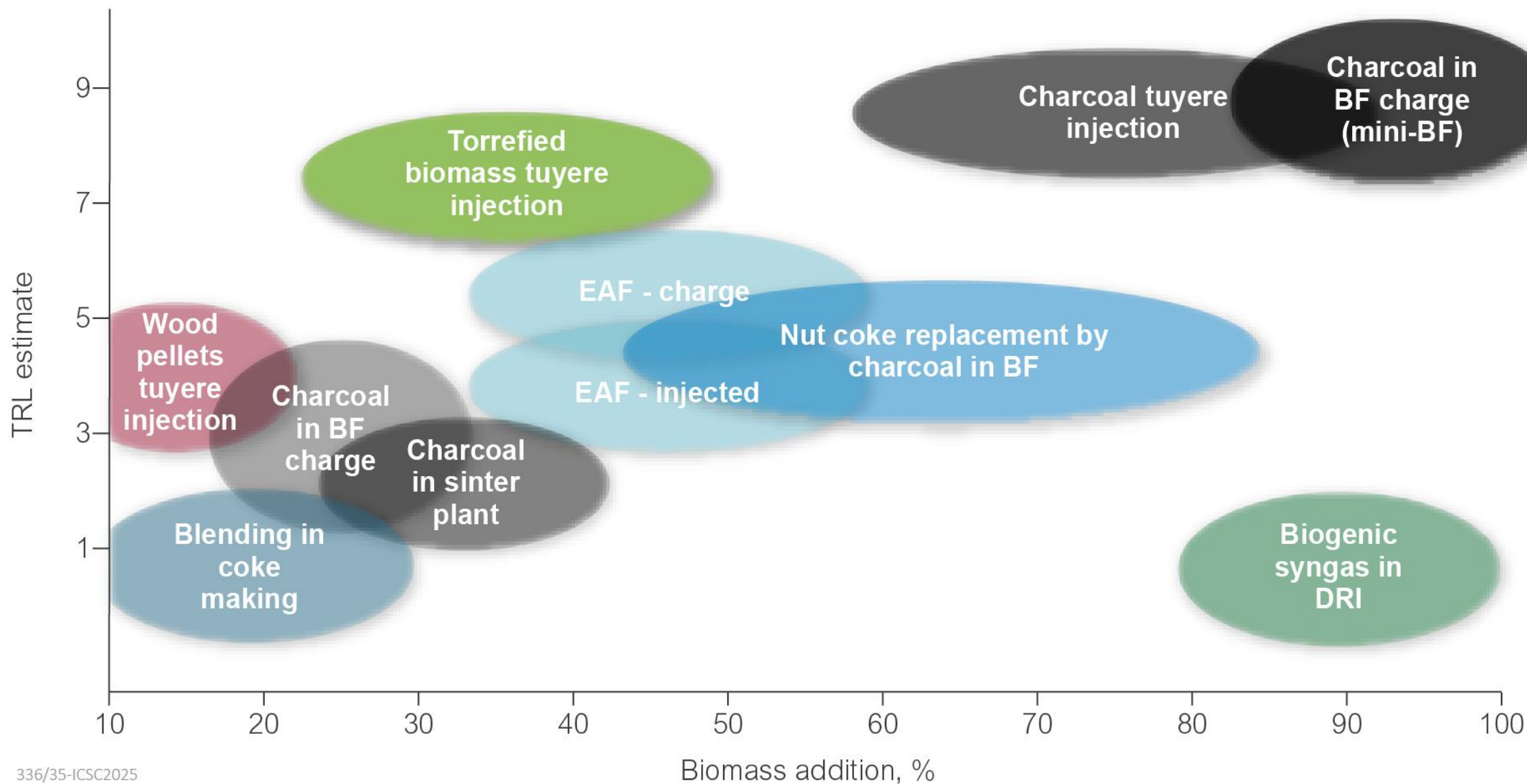
- Ready for implementation
- Wastes and residues of interest (e.g. after pretreatment)
- Anthracite/biomass briquettes demonstrated at scale
- Secure, available supply needed, and economic incentive



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TRL FOR DIFFERENT BIOMASS USE IN I&S



**THERMALLY PRETREATED BIOMASS
AND CHARCOAL ARE ABLE TO
SUBSTITUTE FOR COAL AND COKE
AT VARYING LEVELS IN DIFFERENT
OPERATIONS IN THE I&S PLANT**



CASE STUDY



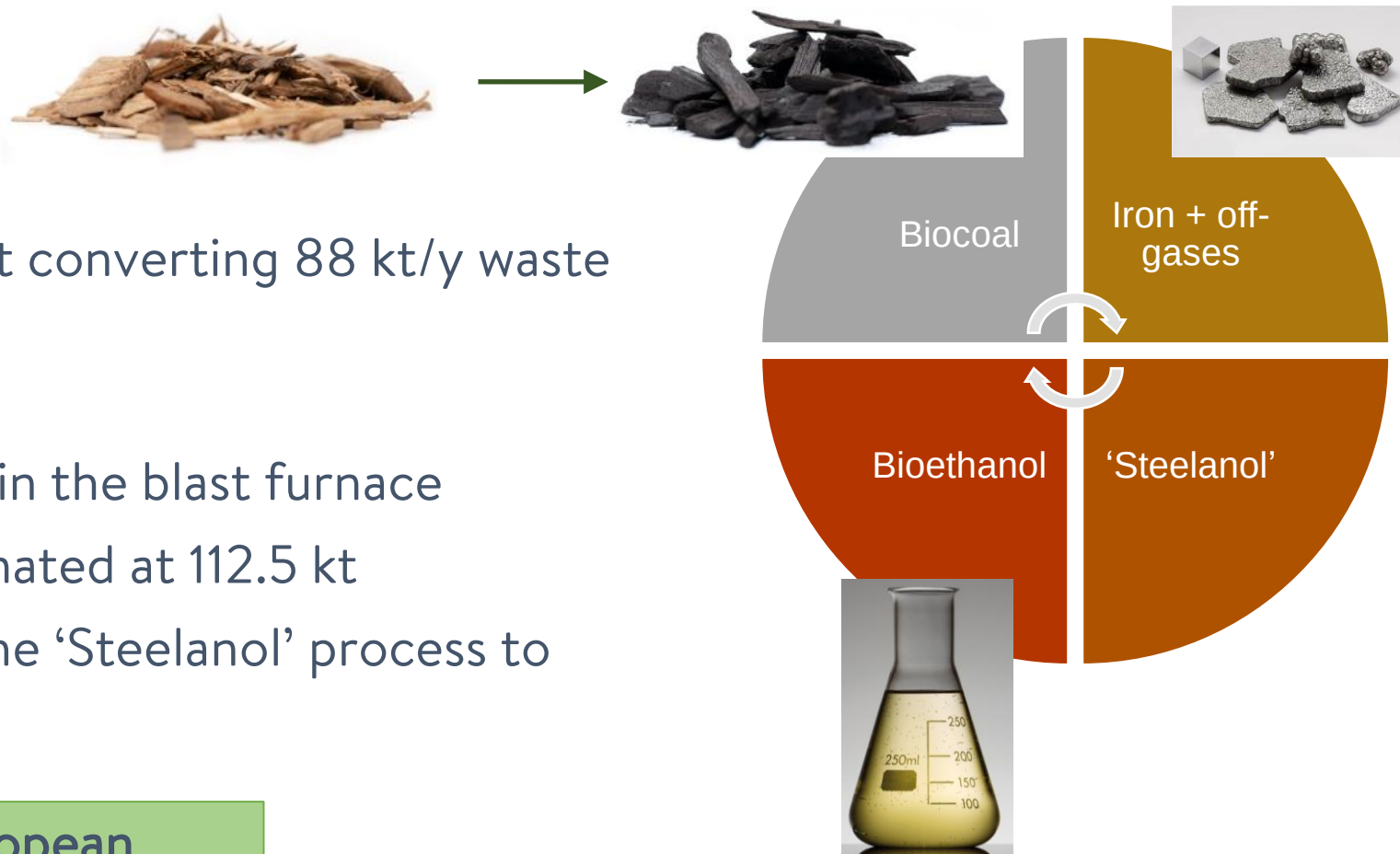


ARCELORMITTAL – TORERO PLANT, BELGIUM

ArcelorMittal – global
steel producer
59 Mt steel, 2022

- Industrial scale torrefaction plant converting 88 kt/y waste wood to 37.5 kt/y 'biocoal'
- €35 million first-of-a-kind plant
- Biocoal will be injected with PCI in the blast furnace
- Displacement of fossil CO₂ estimated at 112.5 kt
- Off-gases will be fermented in the 'Steelanol' process to ethanol

Funding from Horizon 2020, European
Investment Bank, Flemish Government



COMMENTS – IRON AND STEEL





BIOMASS SUPPLY CHAIN

- Potential issues with sustainable, economic supply chain - inherent in any bioenergy project
- Kilns vary in sophistication and yields/emissions
- Torrefaction technologies, commercial and use BAT
- Life cycle analysis critical in assessing carbon reduction benefits
- Ensuring positive social impacts and good employment practices
- Secure and affordable supply
- Balancing all these factors and making it economic - key challenge



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POLICY MEASURES

- Early retrofitting of carbon-reducing measures is key
- Bioenergy is one of a suite of options for decarbonising heavy industry
 - Regulation/certification of supply chain critical
- Transition slow and policy efforts are in early stages in some regions
- Technology enablers include
 - Incentives via direct R&D funds
 - Carbon prices
 - Border adjustment tariff
- Increase demand for 'green steel' to create a viable market
- Capital grants and tax credits for decarbonisation pathway
- Major role for CCS, hydrogen, electrification
- Co-benefits are significant!



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**BIOENERGY WILL PLAY A MODEST
ROLE IN DECARBONISING I&S;
INJECTION OF CARBONISED BIOMASS
IS AT HIGHEST TRL. ECONOMICS
VERSUS SUSTAINABILITY CREDENTIALS
IS A CORE ISSUE**



**MANY DECARBONISATION OPTIONS
DELIVER ENERGY AND FINANCIAL
SAVINGS AS WELL AS
ENVIRONMENTAL AND SOCIETAL
BENEFITS**





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THANK YOU FOR LISTENING

ANY QUESTIONS?