

Negative-zero emission opportunities for the Iron and Steel industry on a global scale

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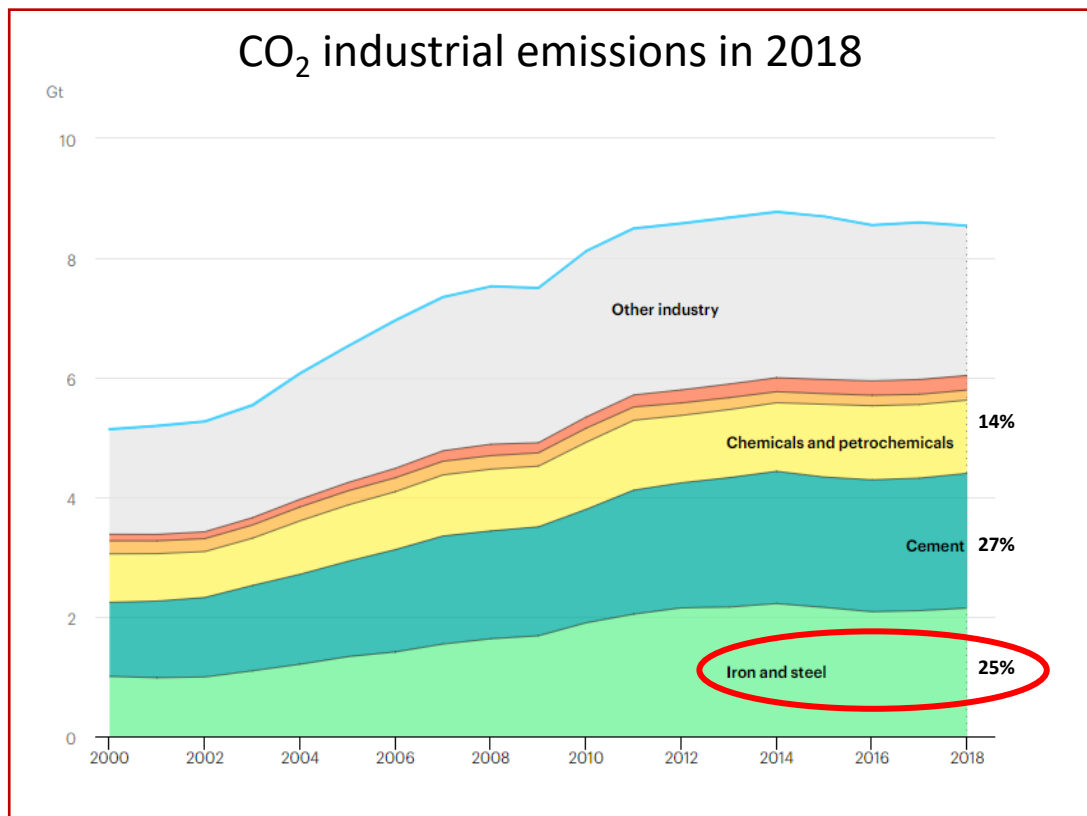


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Steel production: one of the largest CO₂ emitters sectors



Source : IEA (2020), Tracking Industry 2020, IEA, Paris
<https://www.iea.org/reports/tracking-industry-2020>



Steel is an essential material for human development



Steel demand in 2019 was 1.9 Mt and it is expected to significantly increase by 2050

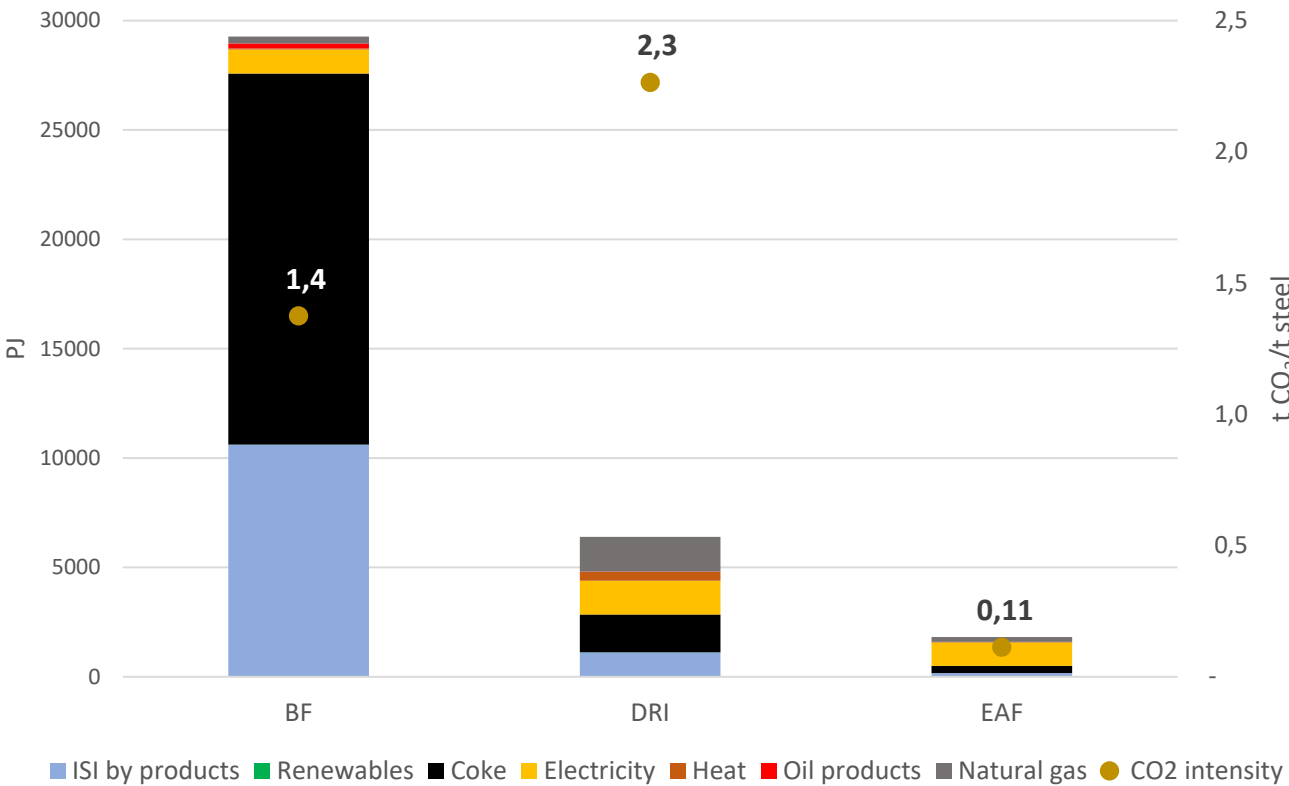


It is needed to deploy solutions to massively reduce greenhouse gas emissions in order to contribute to climate objectives



Current steel production

Energy consumption and energy intensity in the steel sector in 2018



Data source : IEA Beyond 20/20 energy database for energy – World Steel association for steel production

- Fossil fuels are used as fuels and as steel-reducing agents
 - Coal represents around 80% of energy inputs in the steel sector
- Process emissions account for around 8% of total direct CO₂ emissions in the sector
- Some decarbonization options :
 - New technologies: Electrolysis of iron, H₂-based reduction, etc
 - CCS - CCU
 - BECCS - BECCU: negative emissions?





Possible biomass use in steel-producing technologies

Process	Fossil fuel use	Bioproduct substitution	Maximum substitution potential	Reference
Coke oven	Coal	Charcoal	0%-5%	(Mousa et al. 2016)
Pelletization	Coal	Charcoal	0%-100%	(Nwachukwu et al. 2021)
Sintering	Coke	Charcoal	0%-40%	
Blast Furnace / with CCS (including the Top Gas recycling option)	Coke	Charcoal	0%-6%	(Suopajarvi et al. 2017)
	Coal	Charcoal	0%-100%	
	Natural gas	Biomethane	0%-100%	
Direct Reduction of Iron (MIDREX) / with CCS	Natural gas	Biomethane	0%-100%	(Tanzer et al. 2020)
COREX / with CCS	Coal	Charcoal	0%-45%	(Norgate et al. 2012)
	Coke	Charcoal	0%-45%	
HISARNA / with CCS	Coal	Charcoal	0%-45%	
ULCORED / with CCS	Coal	Charcoal	0%-100%	(Tanzer et al. 2020)
	Natural gas	Biomethane	0%-100%	
ULCOWIN	Natural gas	Biomethane	0%-100%	
	Coal	Charcoal	0%-100%	
EAF	Coal	Charcoal	0%-100%	(Yang et al. 2021b)
	Natural gas	Biomethane	0%-100%	
DRI-H2 integrated steel plant	Coal	Charcoal	0%-100%	(Tanzer et al. 2020)
	Natural gas	Biomethane	0%-100%	
Final production of steel	Natural gas	Biomethane	0%-100%	



Modeling approach

- TIAM-FR: *French version of the TIMES Integrated Assessment Model*

Bottom-up

Long-term: **2018-2100**

Multi-regional: 15 regions

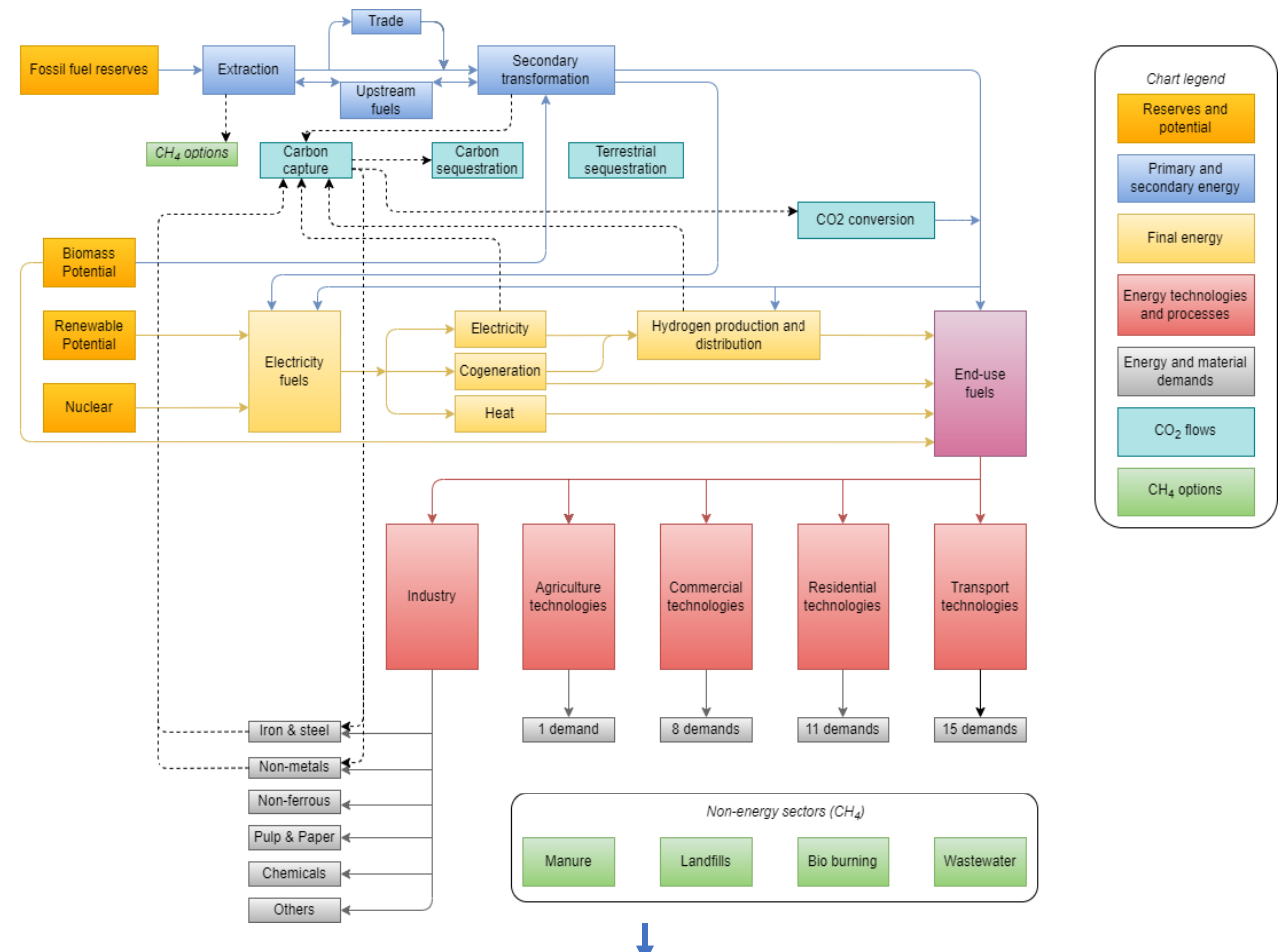
Multi-sectors: 6 sectors

42 demands

585 729 data

11 646 commodities (about 770/region)

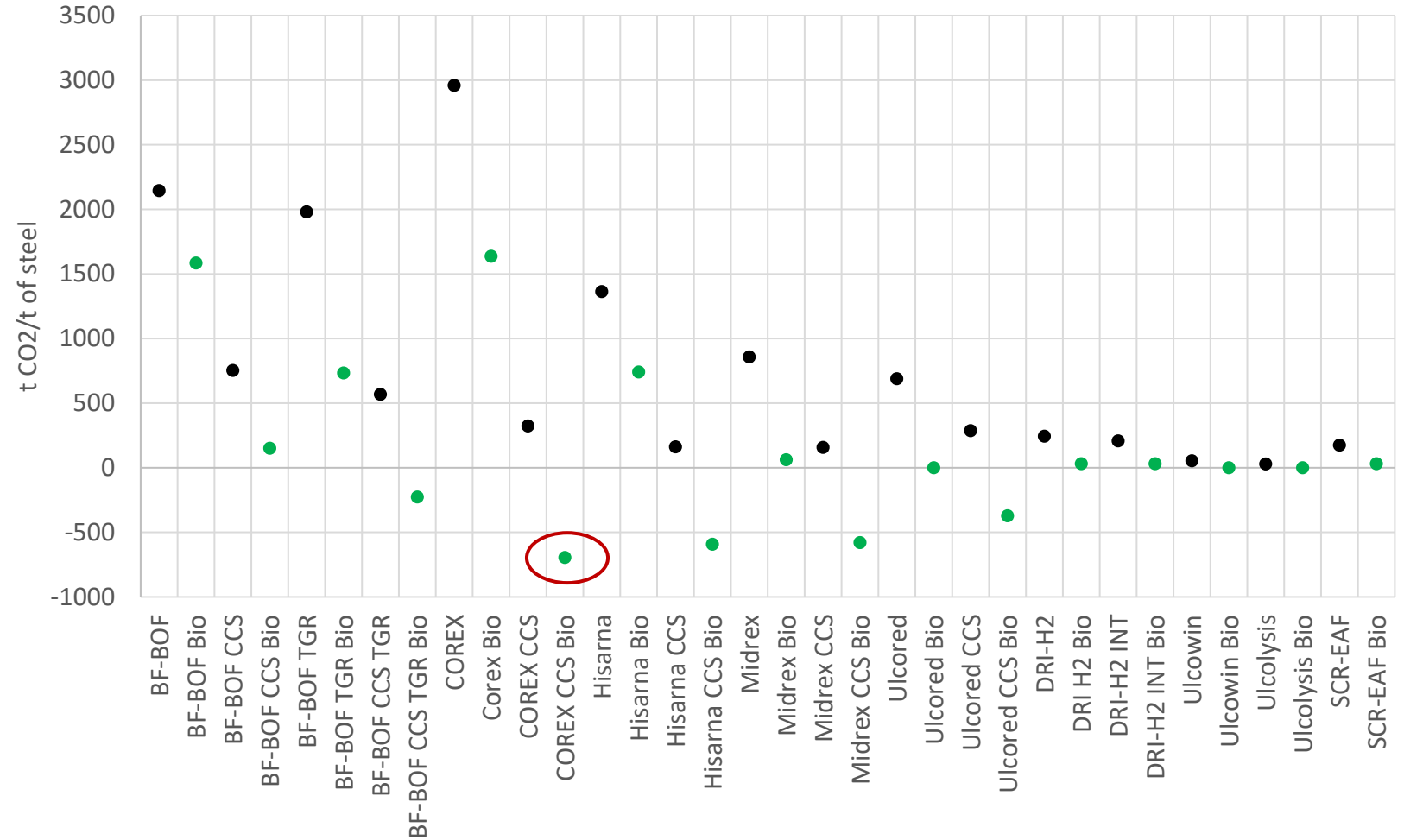
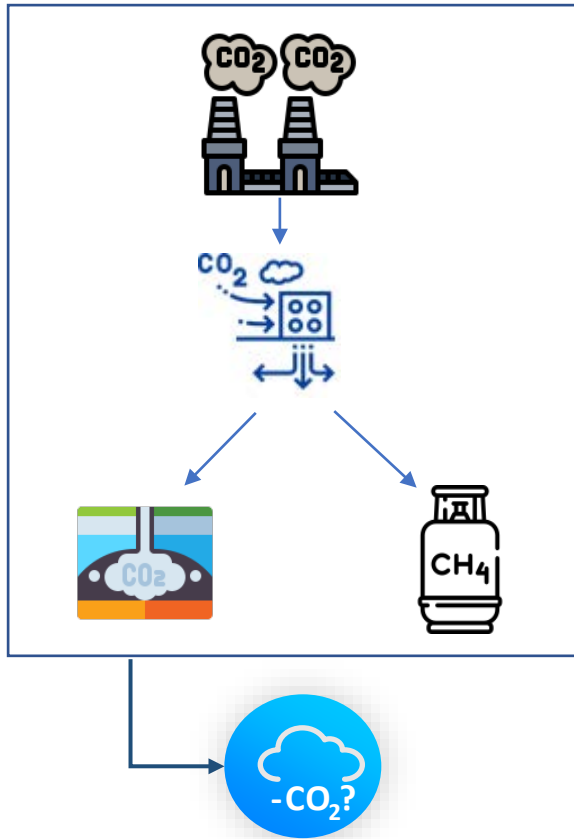
39 817 technologies (about 2 500/region)



$$NPV = \sum_{r=1}^R \sum_{y \in YEARS} (1 + d_{r,y})^{REFYR-y} * ANNCOST(r, y)$$

Biomass representation in TIAM-FR

Detail representation of emissions at each step of consumption and production



Scenarios

1. **Reference (REF)** : does not include any specific decarbonization plan
2. **2°C and 1.5°C (PA)** : limiting the atmospheric temperature increase to 2°C and 1.5°C by 2100
3. **Steel carbon neutral (IIS0)**: forces the iron and steel industry to achieve carbon neutrality by 2050 for developed regions (AUS, CAN, JPN, SKO, USA, WEU) and by 2060 for developing regions (AFR, CHI, CSA, EEU, FSU, IND, MEA, MEX, ODA) in a world where temperature increase is limited to 1.5°C by 2100.
4. **Zero steel emissions by region (IISR_0)** : regions cannot collaborate to reduce their emissions in a world where temperature increase is limited to 1.5°C by 2100.
5. **GWP from the use of biomass (IISB)**: Instead of considering that burning biomass emits zero emissions and that storing 1 ton of biogenic CO₂ generates 1 negative emission, we assign a GWP potential for wood biomass based on its rotation period following the worked developed by (Guest et al. 2013). The temperature increase is also limited to 1.5°C.

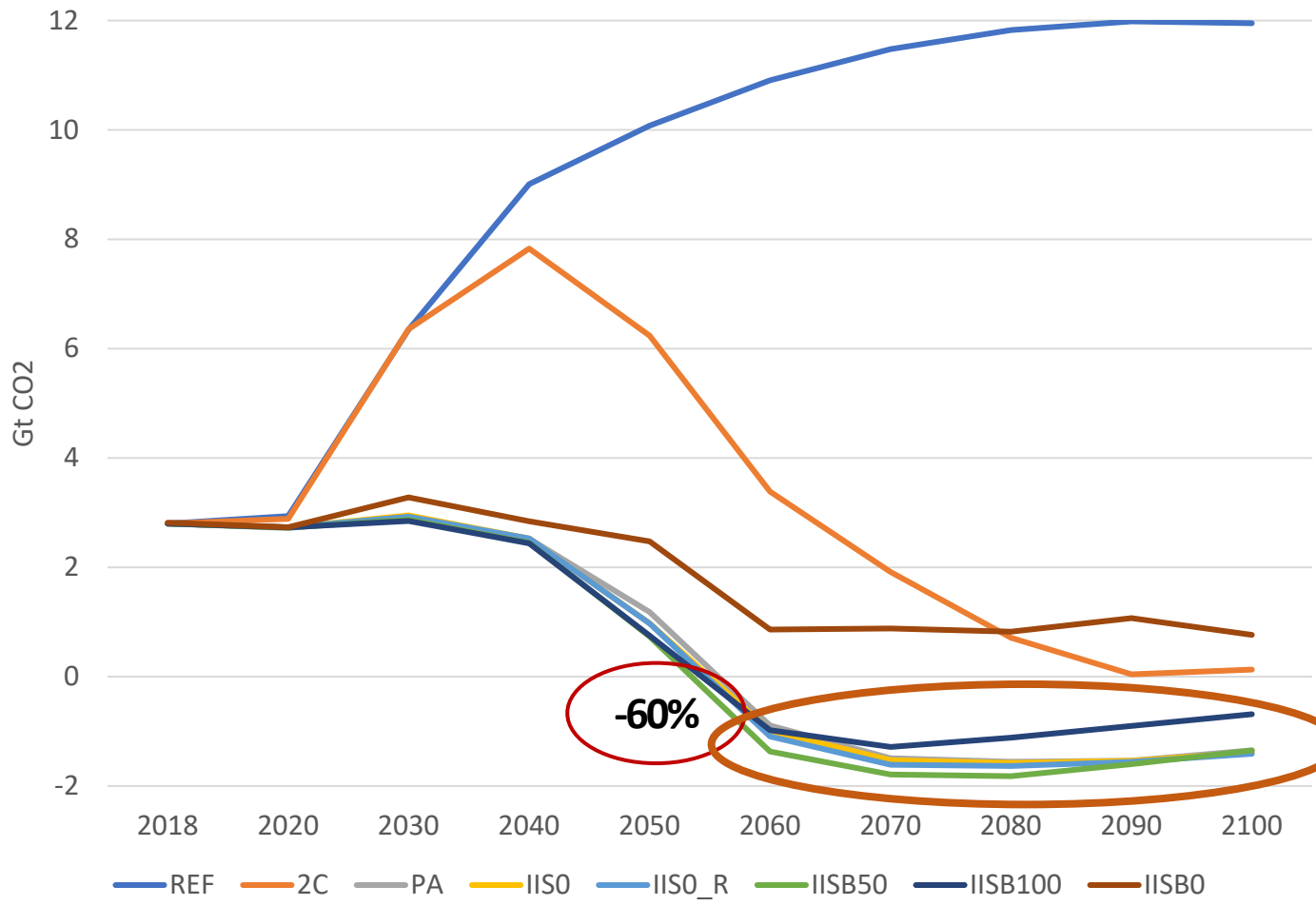
Rotation (years)	GWP (kt CO ₂ /PJ)	Scenario
50	-0.8	IISB50
100	-0.56	IISB100

6. **No biomass use for the steel sector (IISB0)**: How the steel sector would contribute to limit the rise of temperatures to 1.5°C when biomass is not available for the sector



Steel sector net CO₂ emissions by scenario

Net CO₂ emissions in the steel sector by scenario

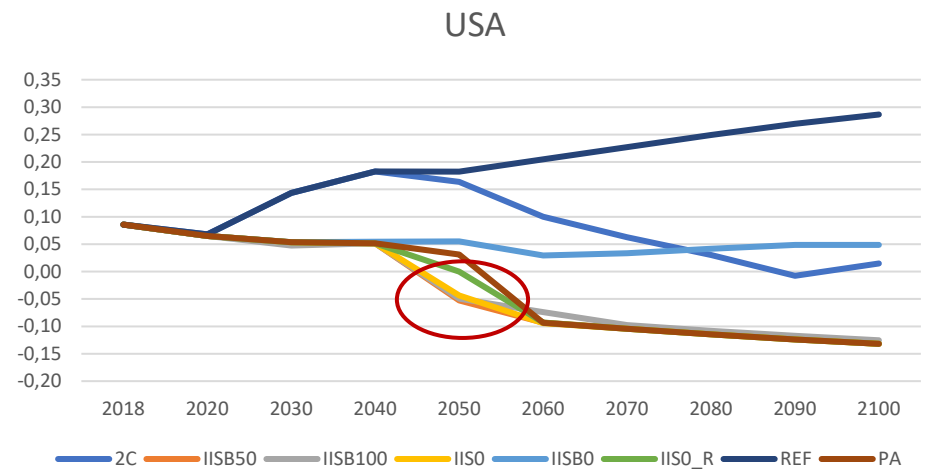
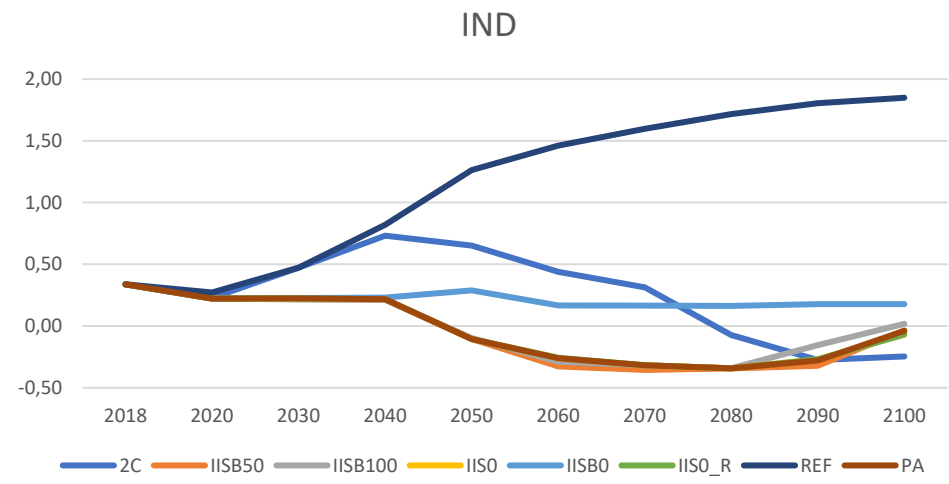
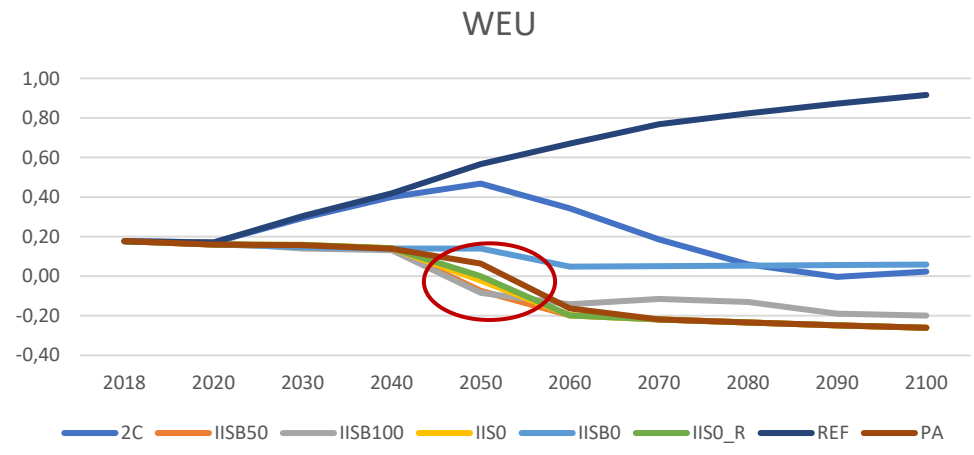
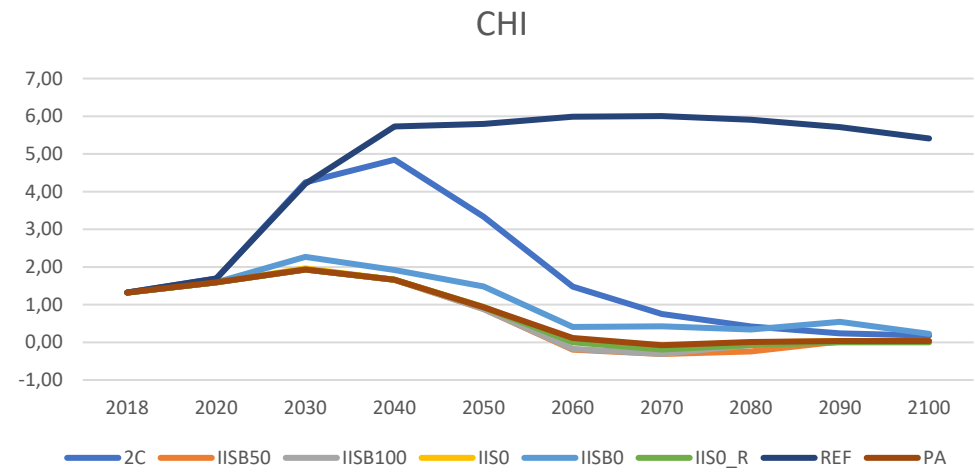


- The ISI must become net negative in order to contribute to the 1.5°C scenario
- NETs appear to be essential for the ISI decarbonization
- Biomass rotation has an important impact over NETs deployment

NETs deployment



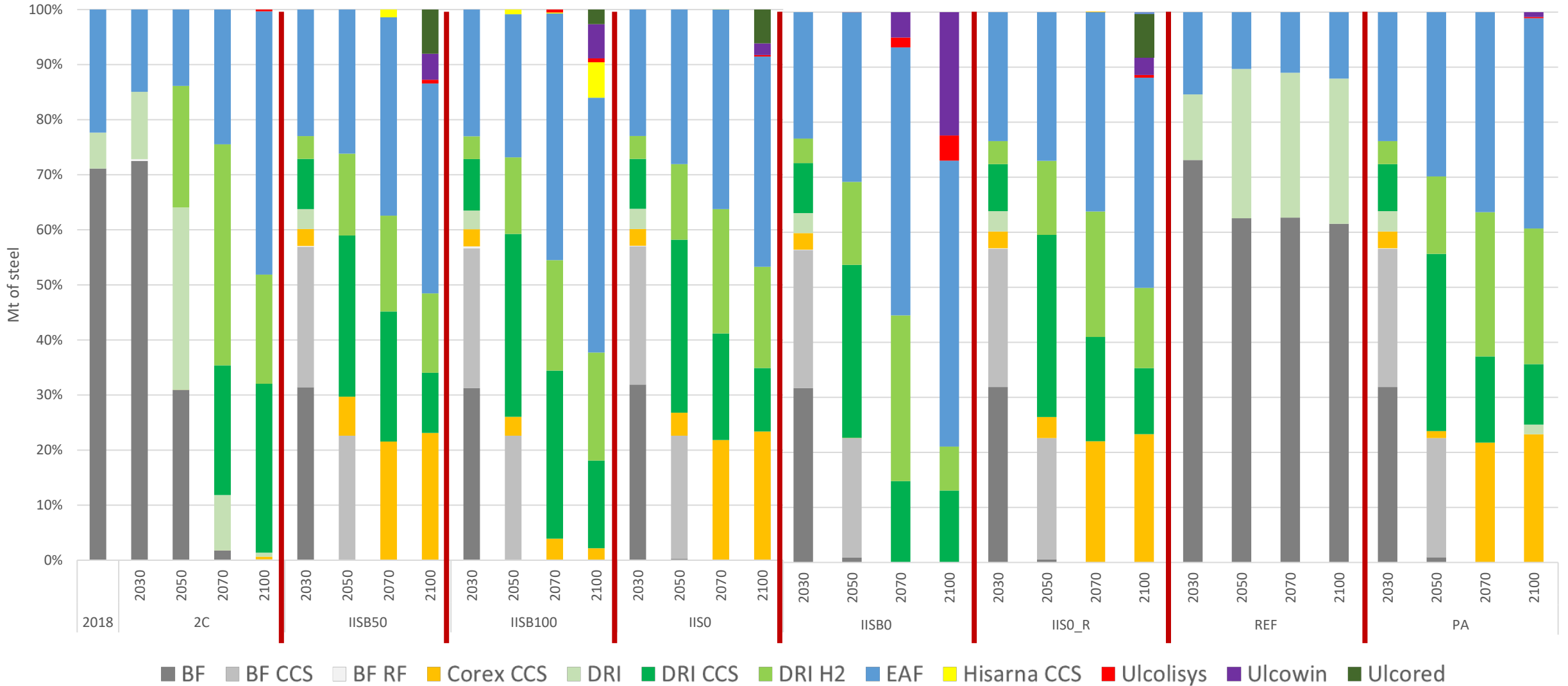
Steel sector net CO₂ emissions by scenario for selected regions





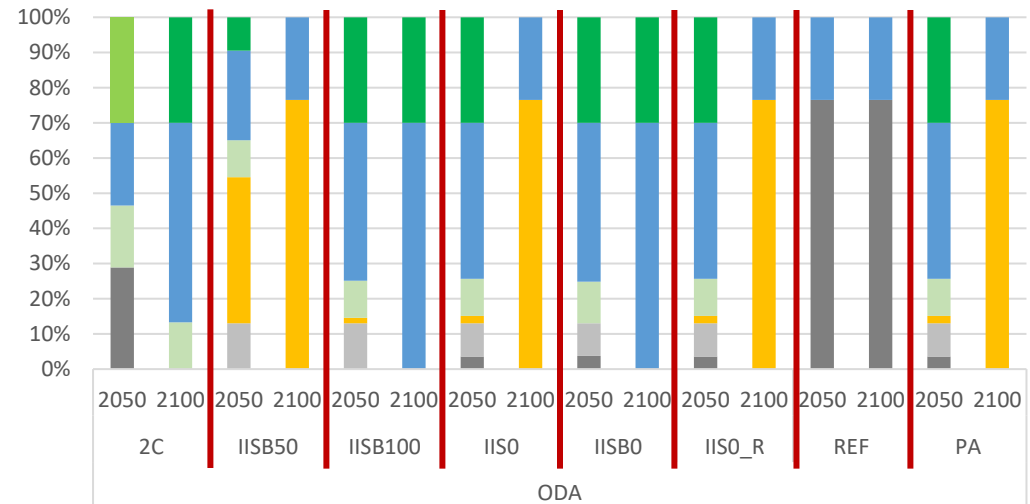
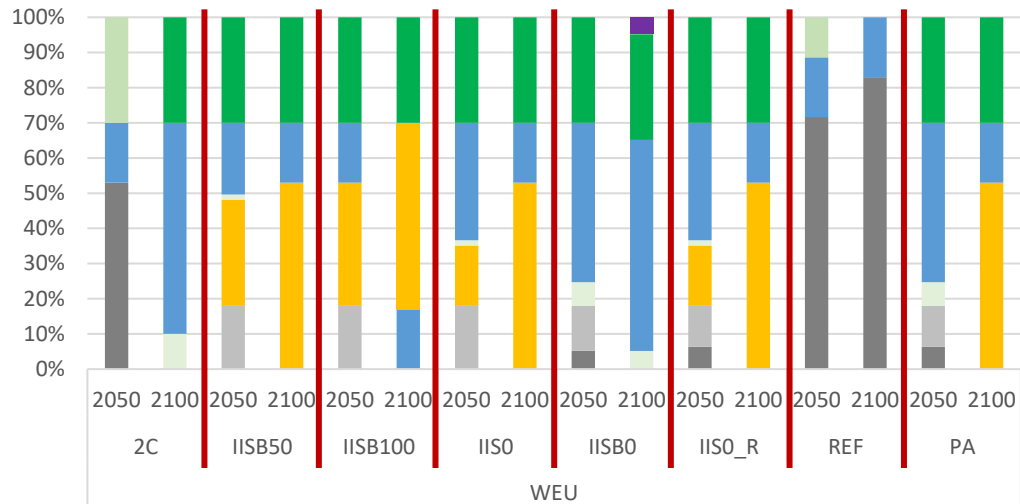
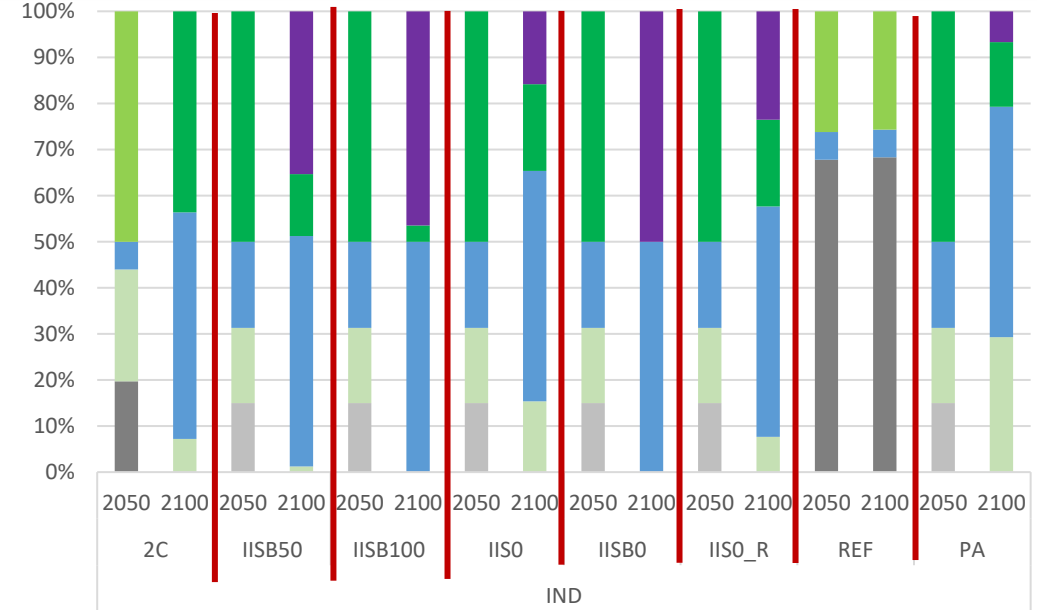
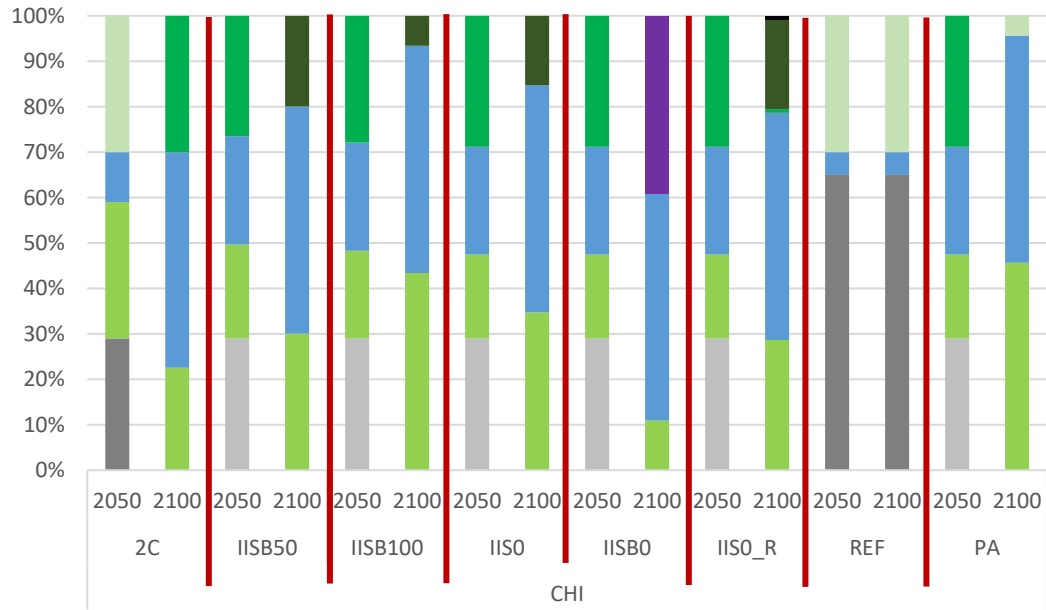
What about technological deployment

Developed steel producing technologies by scenario



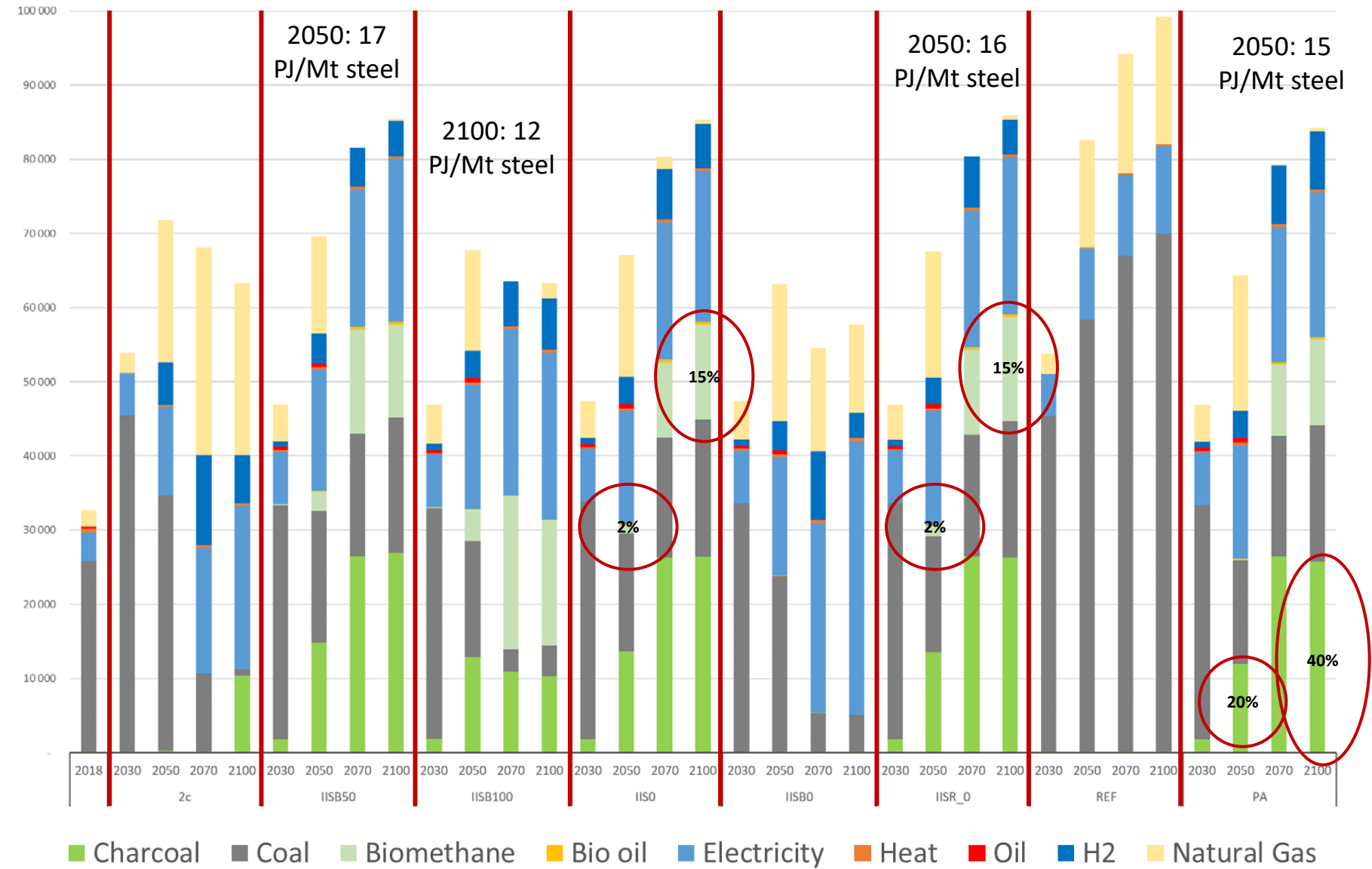


Steel production for selected regions





What about energy consumption?





Marginal cost of steel

\$/t steel	2020	2030	2040	2050	2060	2070	2080	2090	2100
2C	640	626	640	668	695	718	740	752	770
IISB50	748	768	808	864	715	676	690	737	752
IISB100	761	775	811	941	801	791	812	824	931
IISO	726	755	790	845	724	675	708	739	758
IISB0	106	110	399	882	835	889	925	940	1 061
IISO_R	726	756	789	863	722	677	711	741	764
REF	633	612	613	609	611	613	613	614	615
PA	730	756	782	846	715	666	701	731	747

- By 2050:
 - Marginal cost of steel would increase in 40% for PA, and IISO, while it is 45% higher in IISR_0 with respect to 2018
 - For IISB0 and IISB100 marginal cost of steel would be 50% higher than 2018



Conclusion

- The steel sector must engage in a deep decarbonization pathway if it is aimed to limit the rise of temperatures to 1.5°C.
- NETs are essential for the decarbonization of the steel sector in 1.5°C scenarios, and they can massively contribute to the decarbonization of the rest of the energy system as well
- NETs deployment must be accompanied by other low-carbon technologies, namely the DRI-H₂, and EAF
- When using high rotation biomass in the ISI, its use might decrease but its role in decarbonizing the steel production is still significant

Negative-zero emission opportunities for the Iron and Steel industry on a global scale

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Thanks you for your attention



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