Hydrogen production by Methane Pyrolysis

An alternative route to meet the steel industry's demand towards low carbon steel production

Robert OBENAUS-EMLER | Montanuniversität Leoben

31/10/2024

ESTEP
European Steel Technology Platform
20 years together

H2 FOR GREEN STEEL
3rd INTERNATIONAL CONFERENCE
meets
A CIRCULAR ECONOMY DRIVEN BY THE EUROPEAN STEEL

voestalpine
ONE STEP AHEAD.

PRIMETALS TECHNOLOGIES

SCoRe A+
Strategic Core Research Area

Hydrogen production by
Methane Pyrolysis

Robert OBENAUS–EMLER

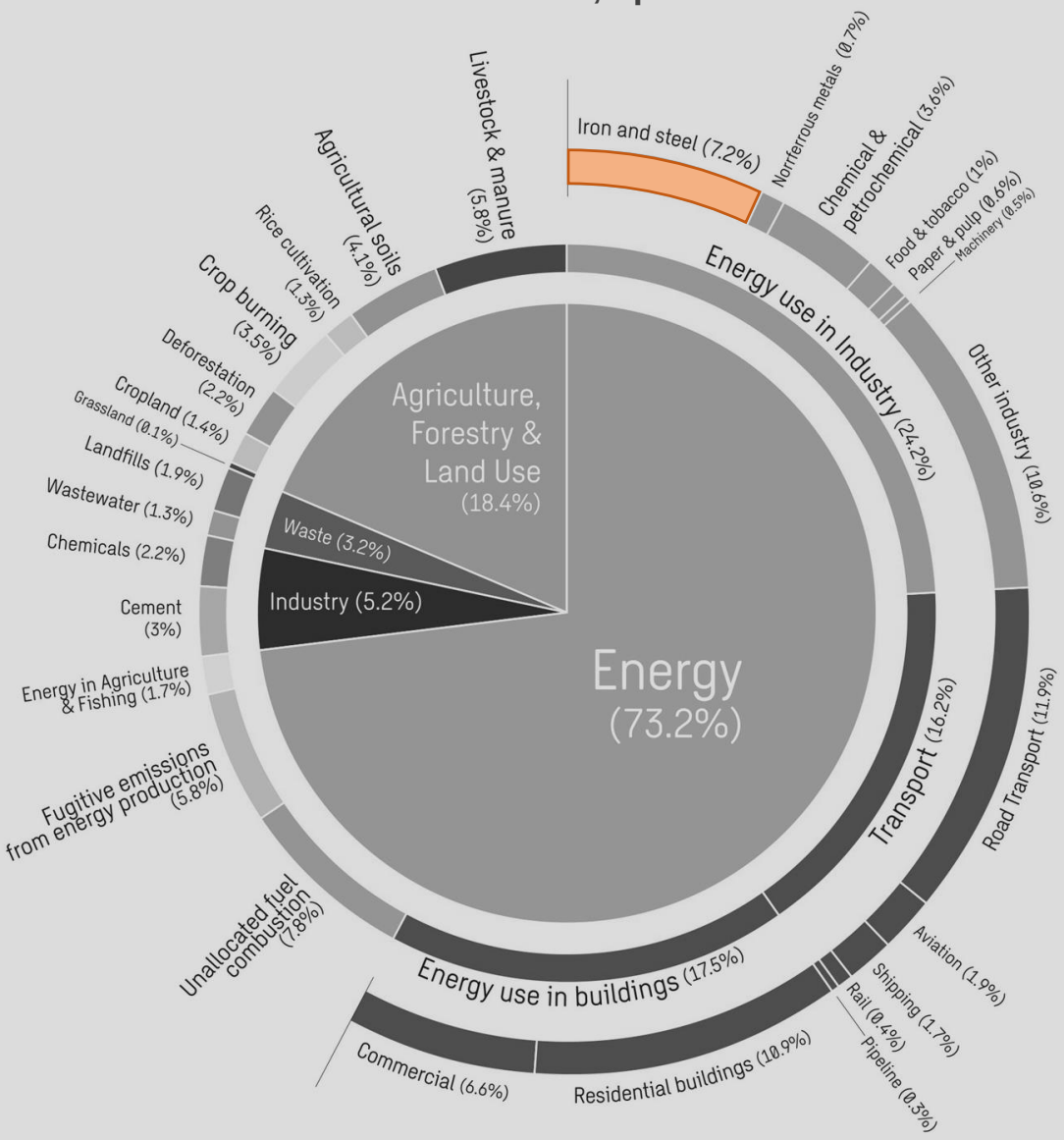
Head of Resouces Innovation Center
Coordinator of SCoRe A+ Hydrogen and Carbon

MONTAN UNIVERSITÄT LEOBEN

RIC Leoben

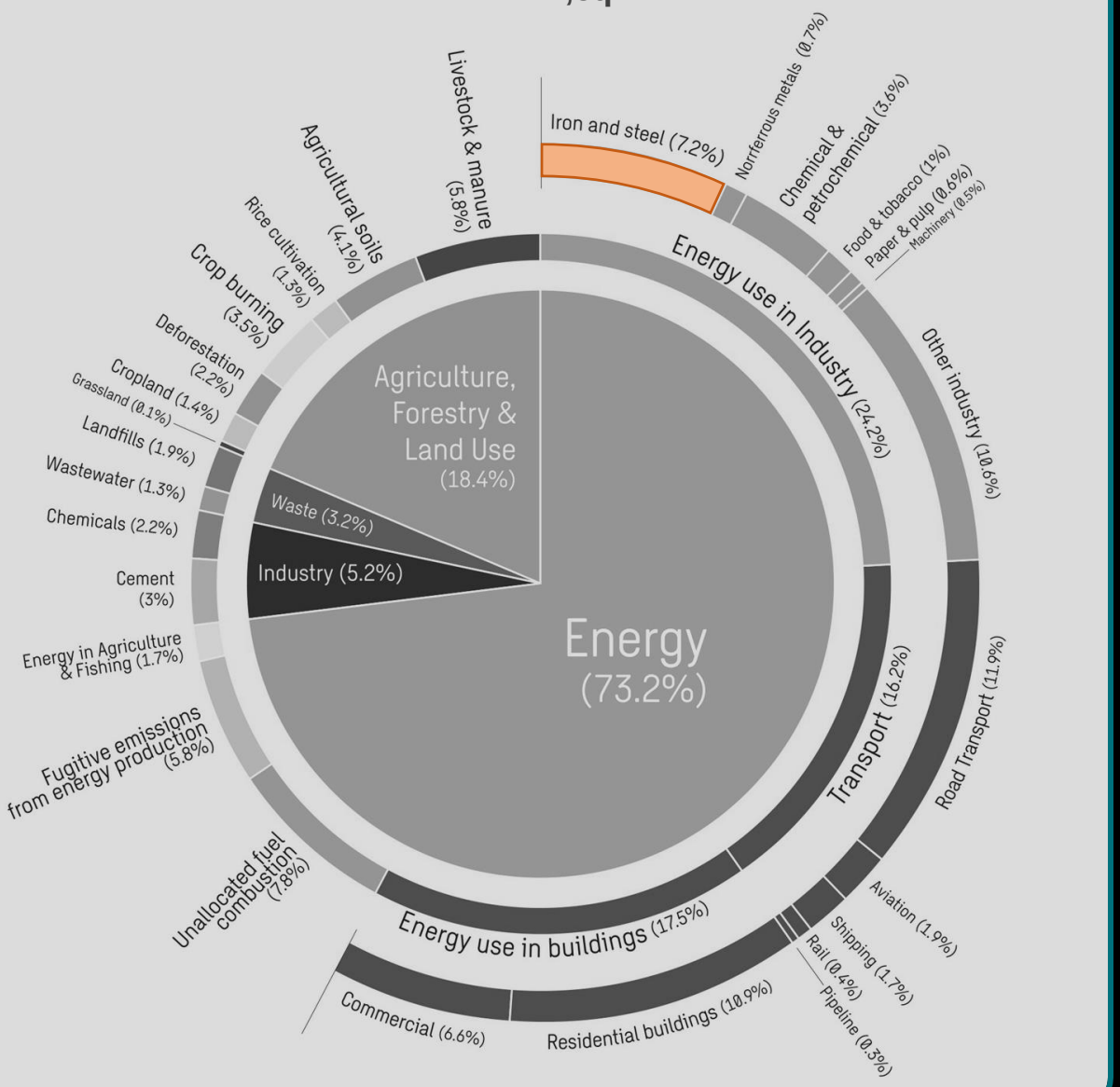
WHERE RESEARCH MEETS FUTURE

Global emissions as $CO_{2,eq}$



Our World In Data (2020)

Global emissions as $CO_{2,eq}$

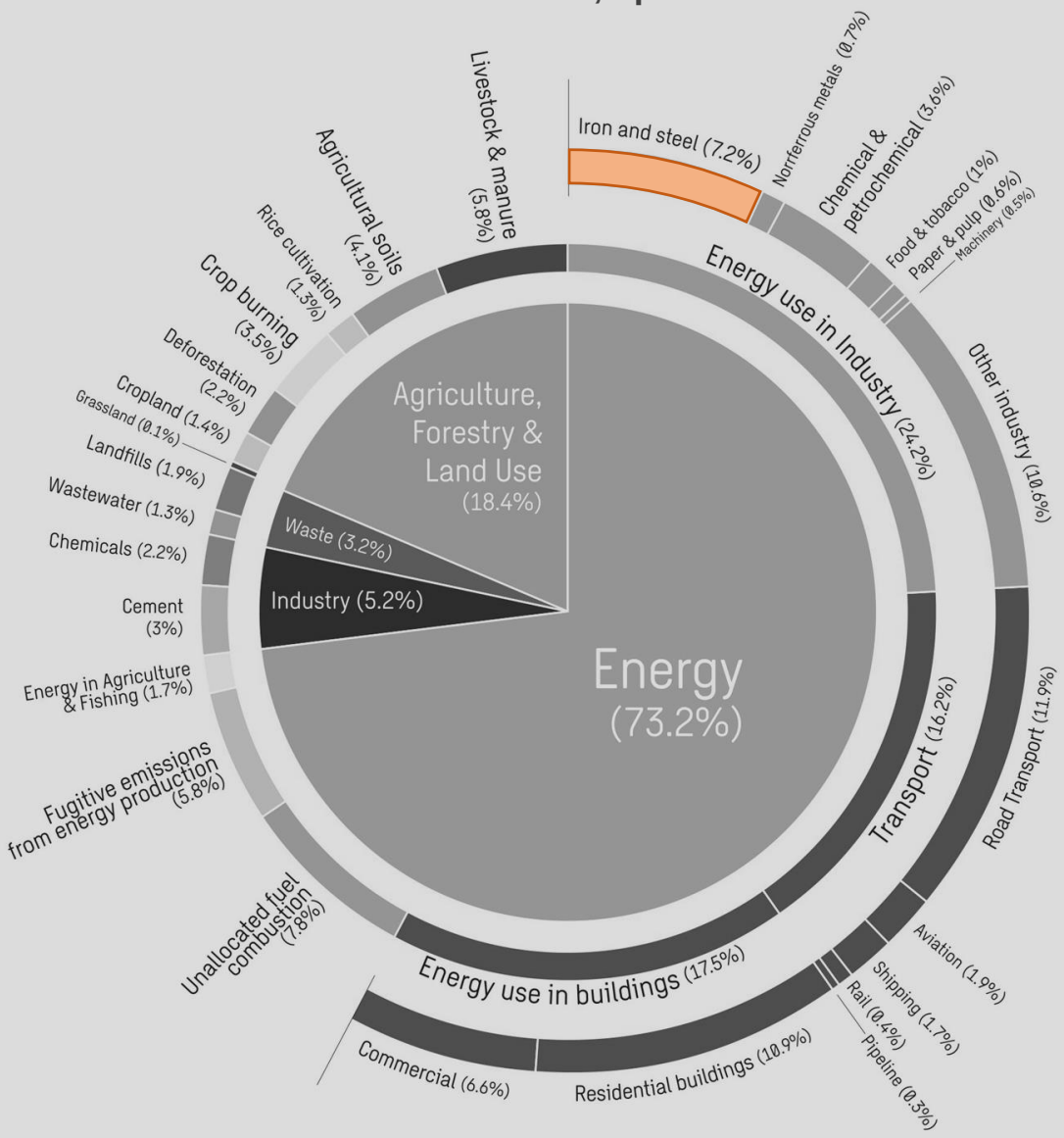


Our World In Data (2020)

Iron and steel industry

3.1 Gt / a (7.2 %)

Global emissions as $CO_{2,eq}$

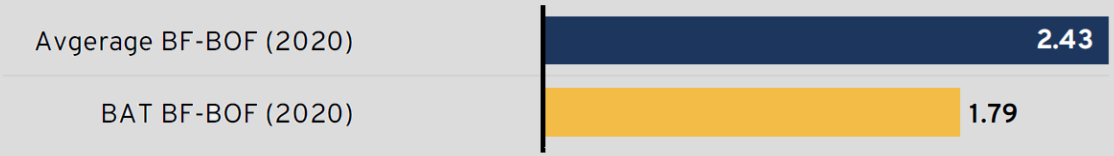


Our World In Data (2020)

Iron and steel industry

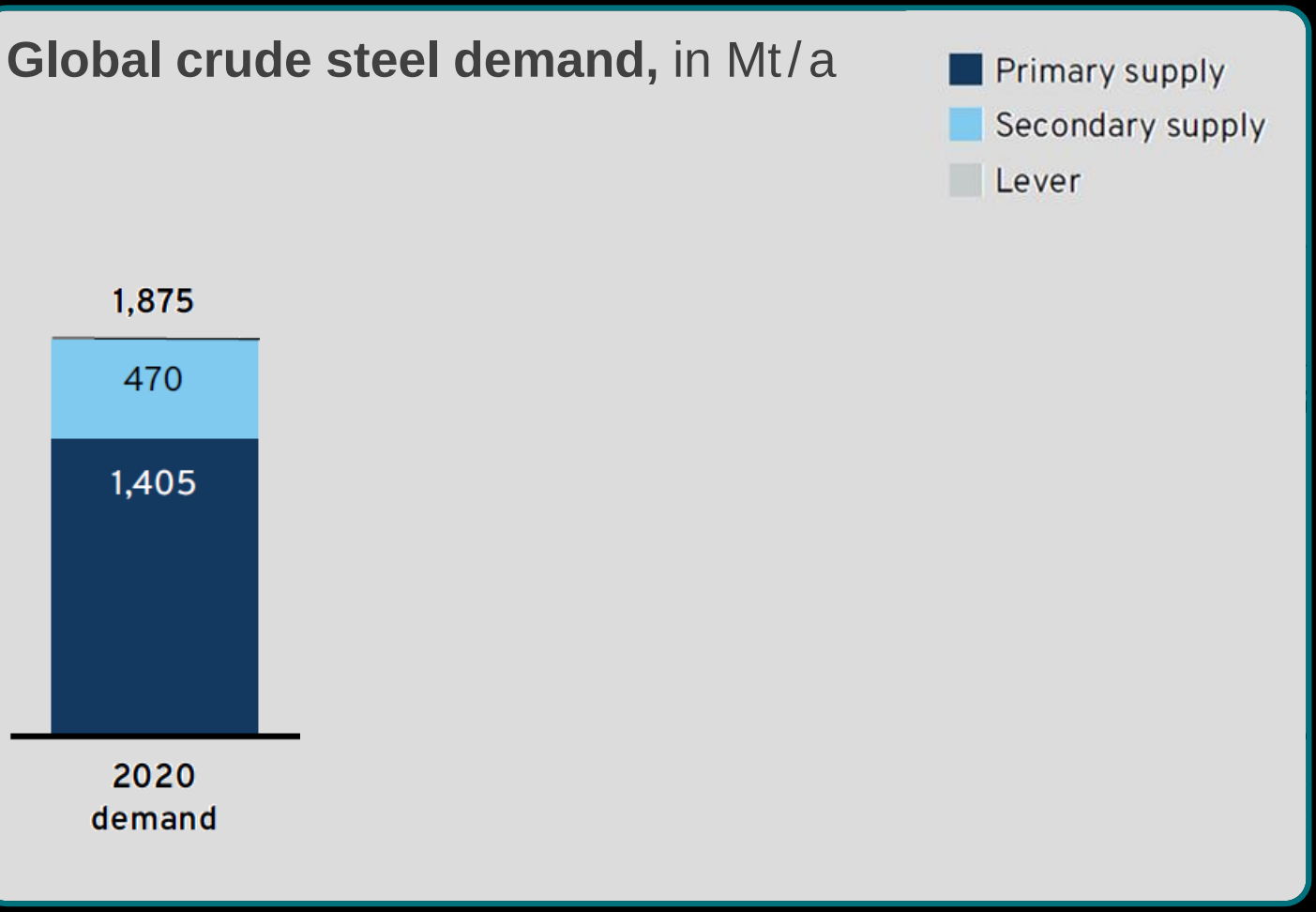
3.1 Gt / a (7.2 %)

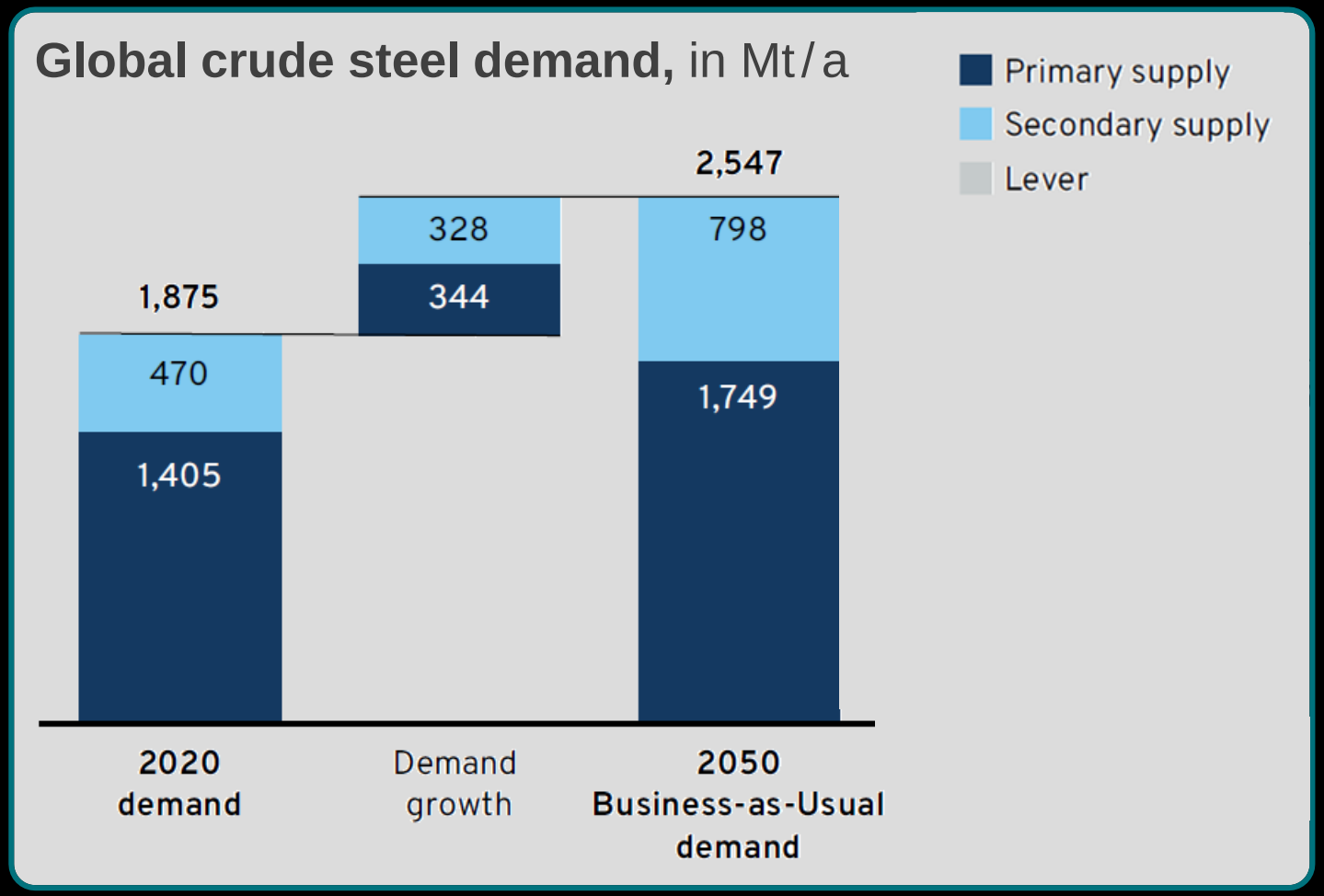
Specific Emissions, in kg $CO_{2,eq}$ / kg steel

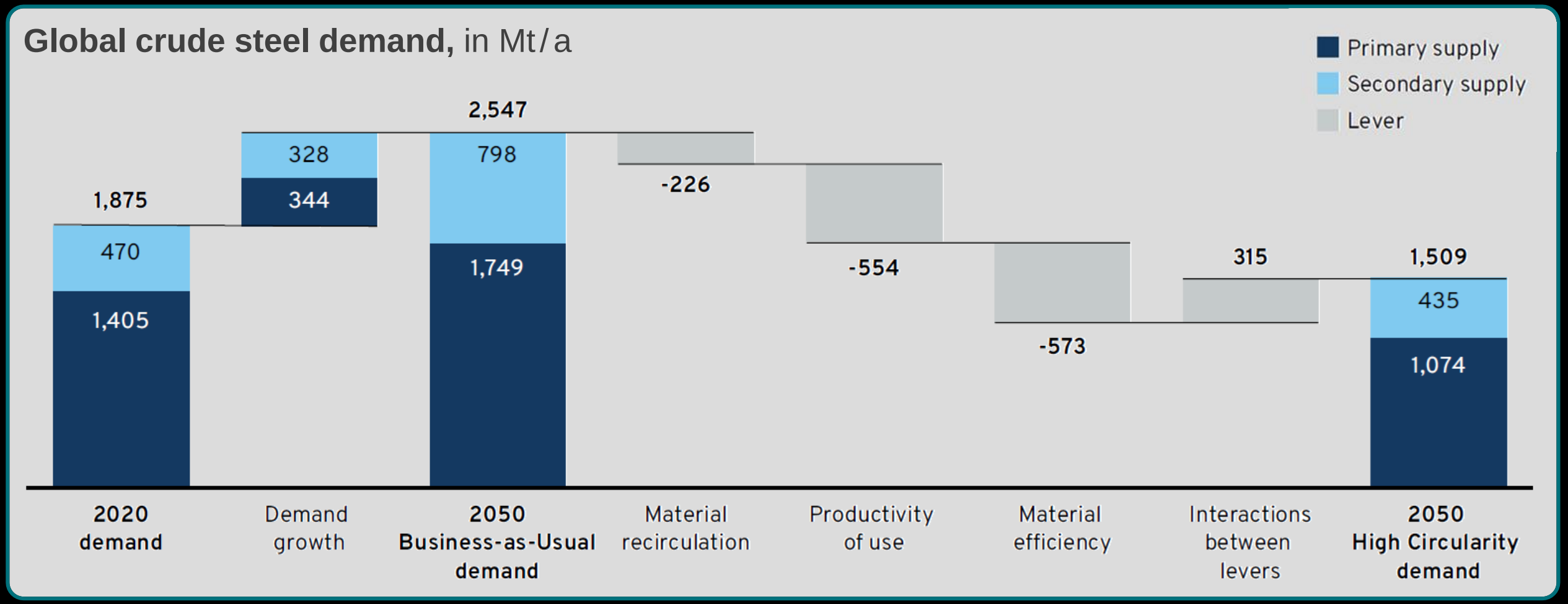


Mission Possible Partnership | Steel Transition Strategy 9/22

Global crude steel demand, in Mt/a



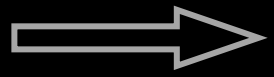

Global crude steel demand, in Mt/a
Primary supply
Secondary supply
Lever
2,547
328
798
1,875
344
470
1,749
1,405
2020 demand
Demand growth
2050 Business-as-Usual demand

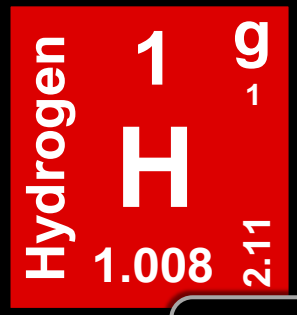

Global crude steel demand, in Mt/a
Primary supply
Secondary supply
Lever
1,875
470
1,405
328
344
2,547
798
1,749
-226
-554
-573
315
1,509
435
1,074
2020 demand
Demand growth
2050 Business-as-Usual demand
Material recirculation
Productivity of use
Material efficiency
Interactions between levers
2050 High Circularity demand

oil and gas

water

biomass





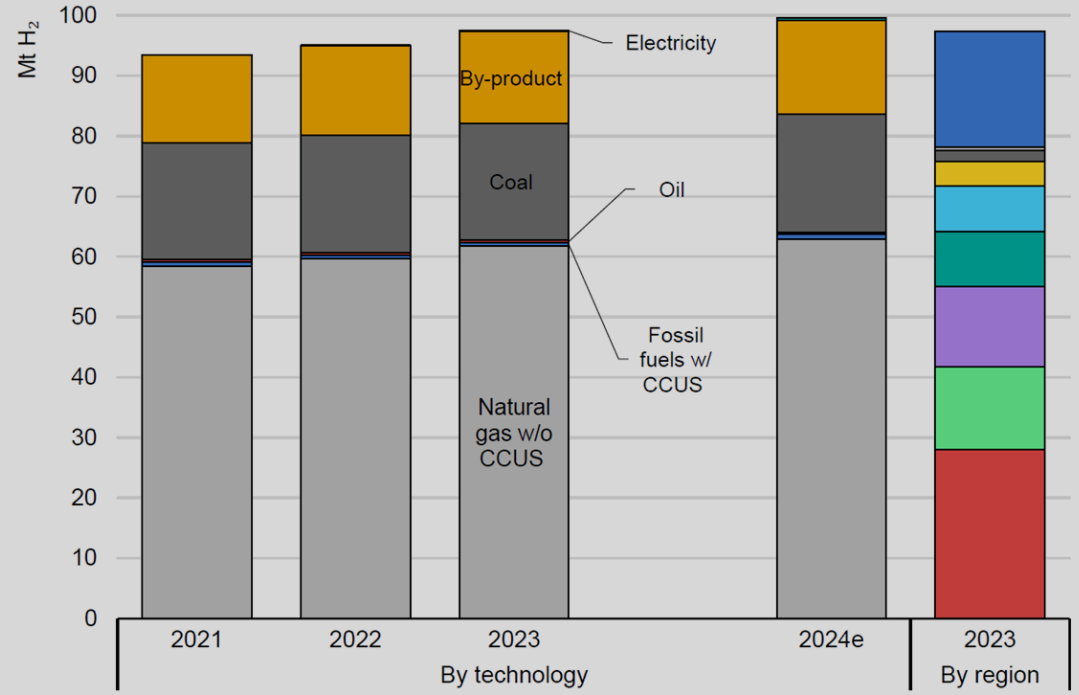
Hydrogen production

oil and gas

water

biomass

Global hydrogen production, in Mt/a



Notes: By-product hydrogen from the chlor-alkali industry is not included. CCUS = carbon capture utilisation and storage; RoW = rest of world; 2024e= estimate for 2024. The estimated value for 2024 is a projection based on trends observed until June 2024.

IEA Global Hydrogen Review (2024)

oil and gas

water

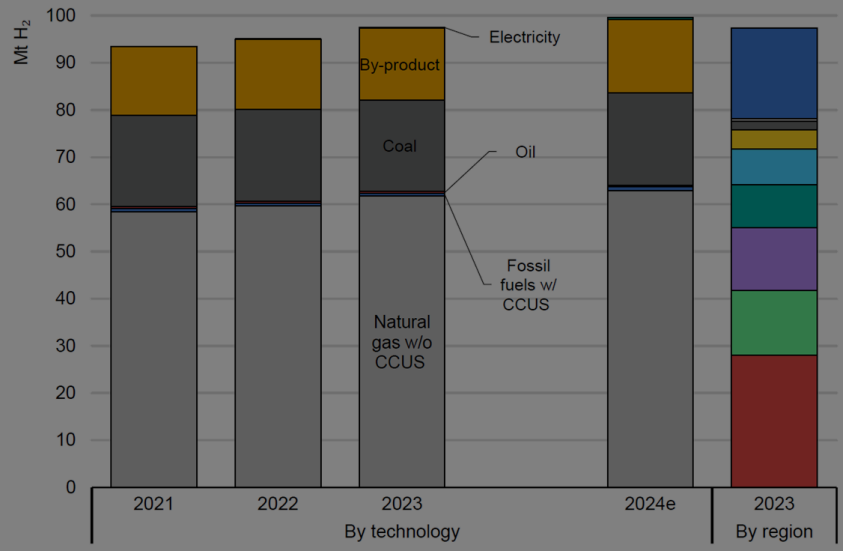
biomass

GREY HYDROGEN

Generated through SMR* using natural gas or fossil fuels

*SMR = steam methane

Global hydrogen production, in Mt/a



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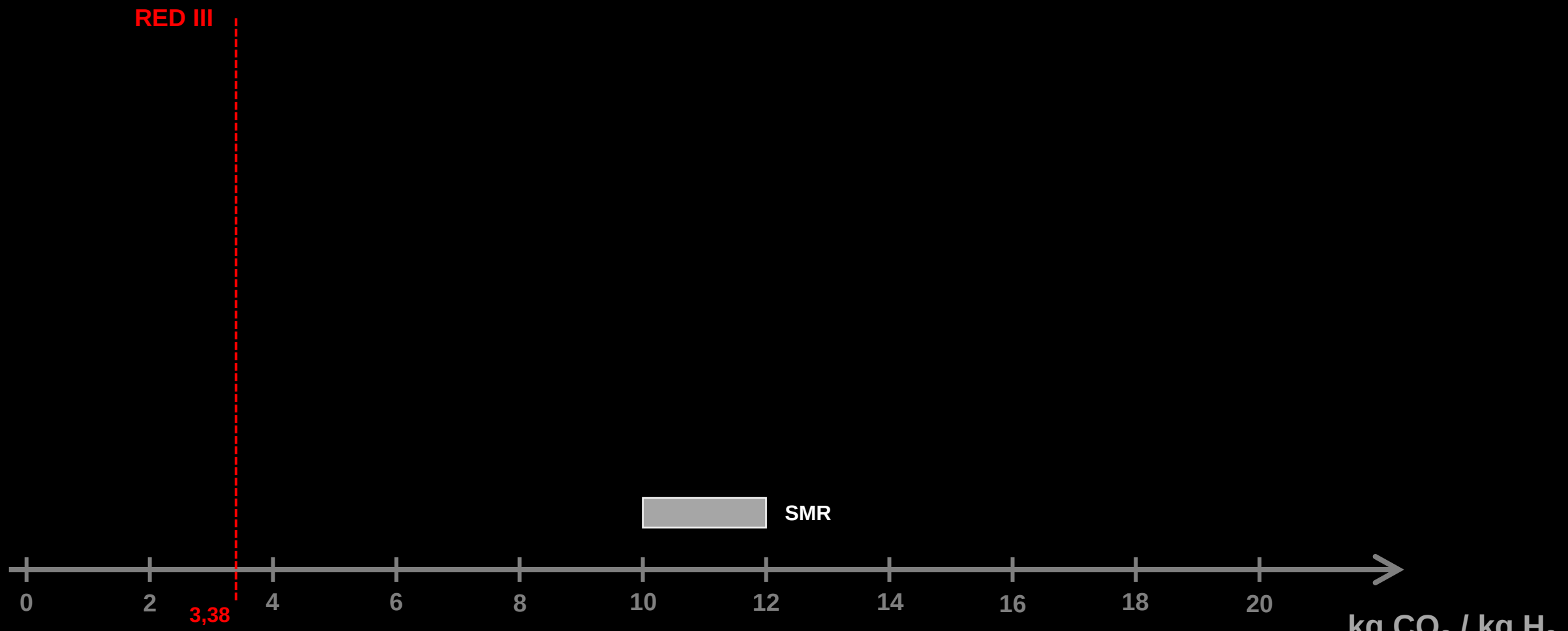
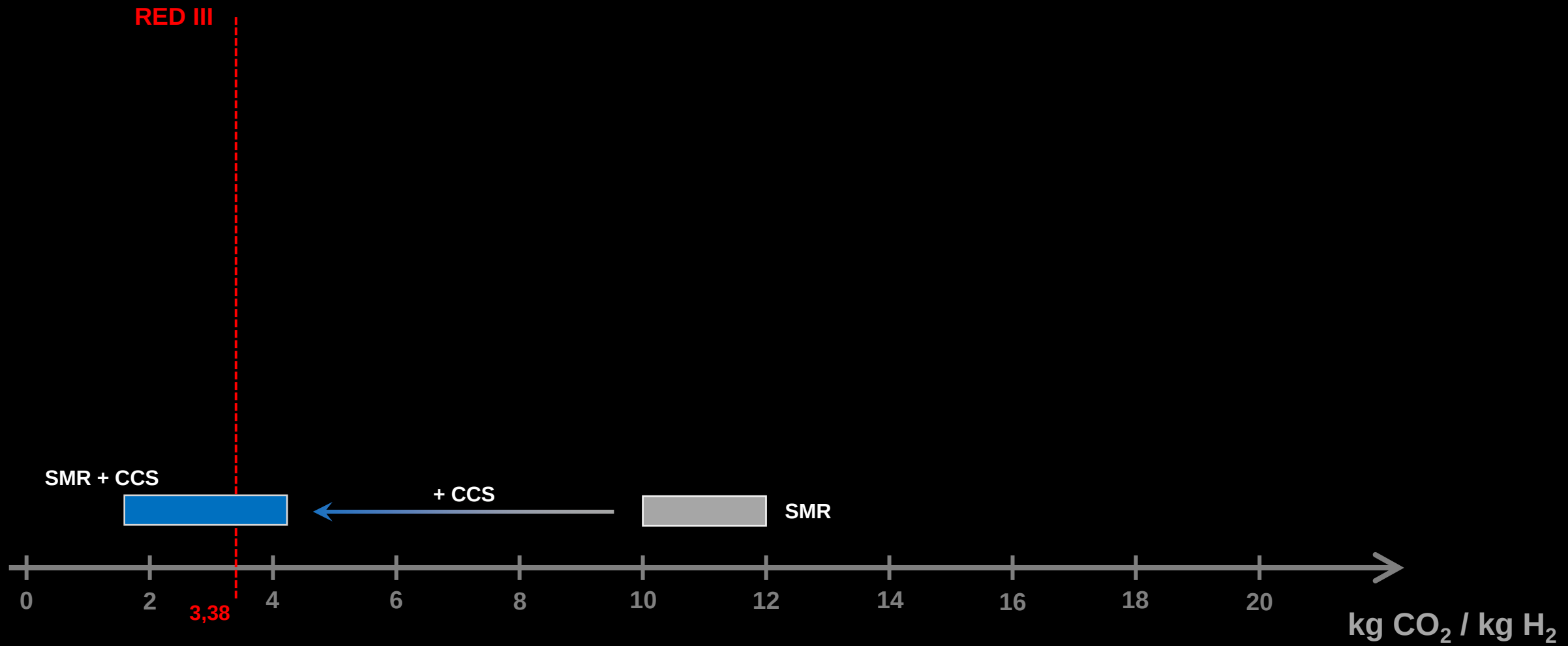
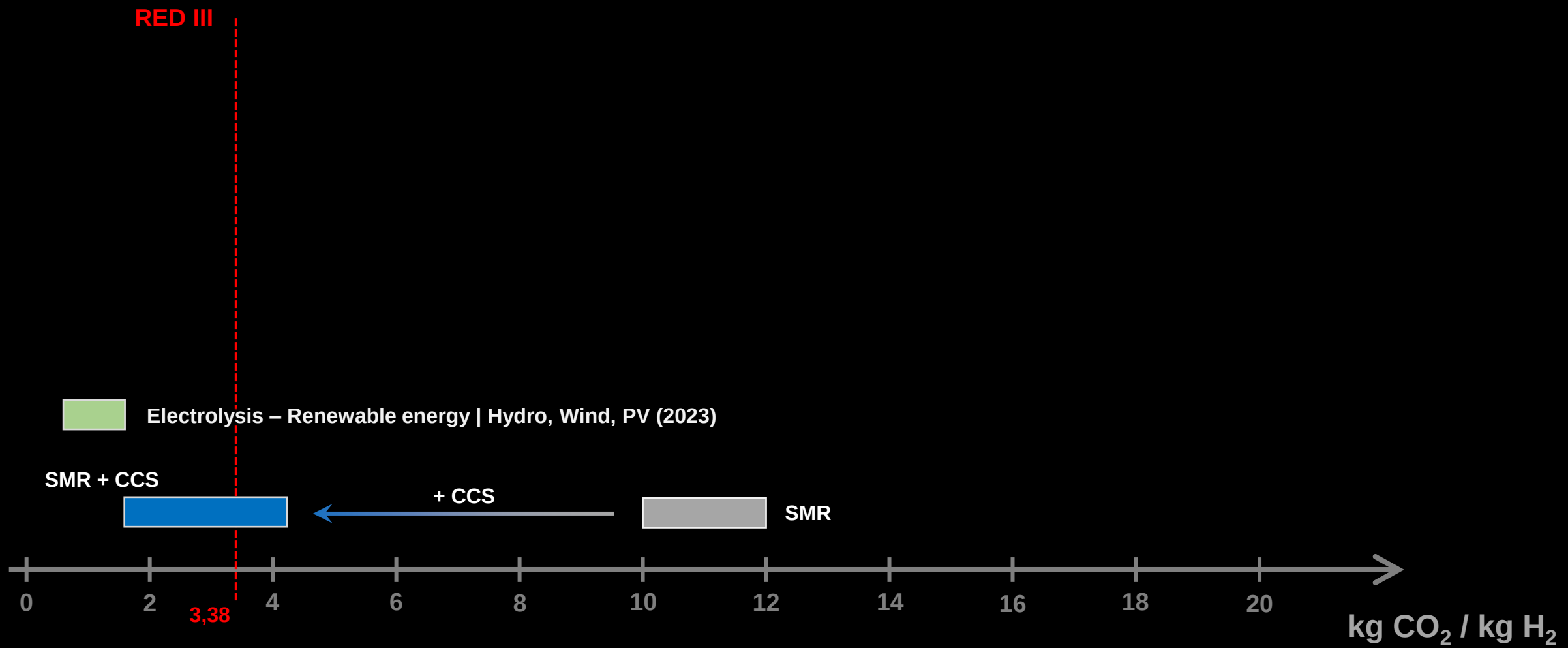
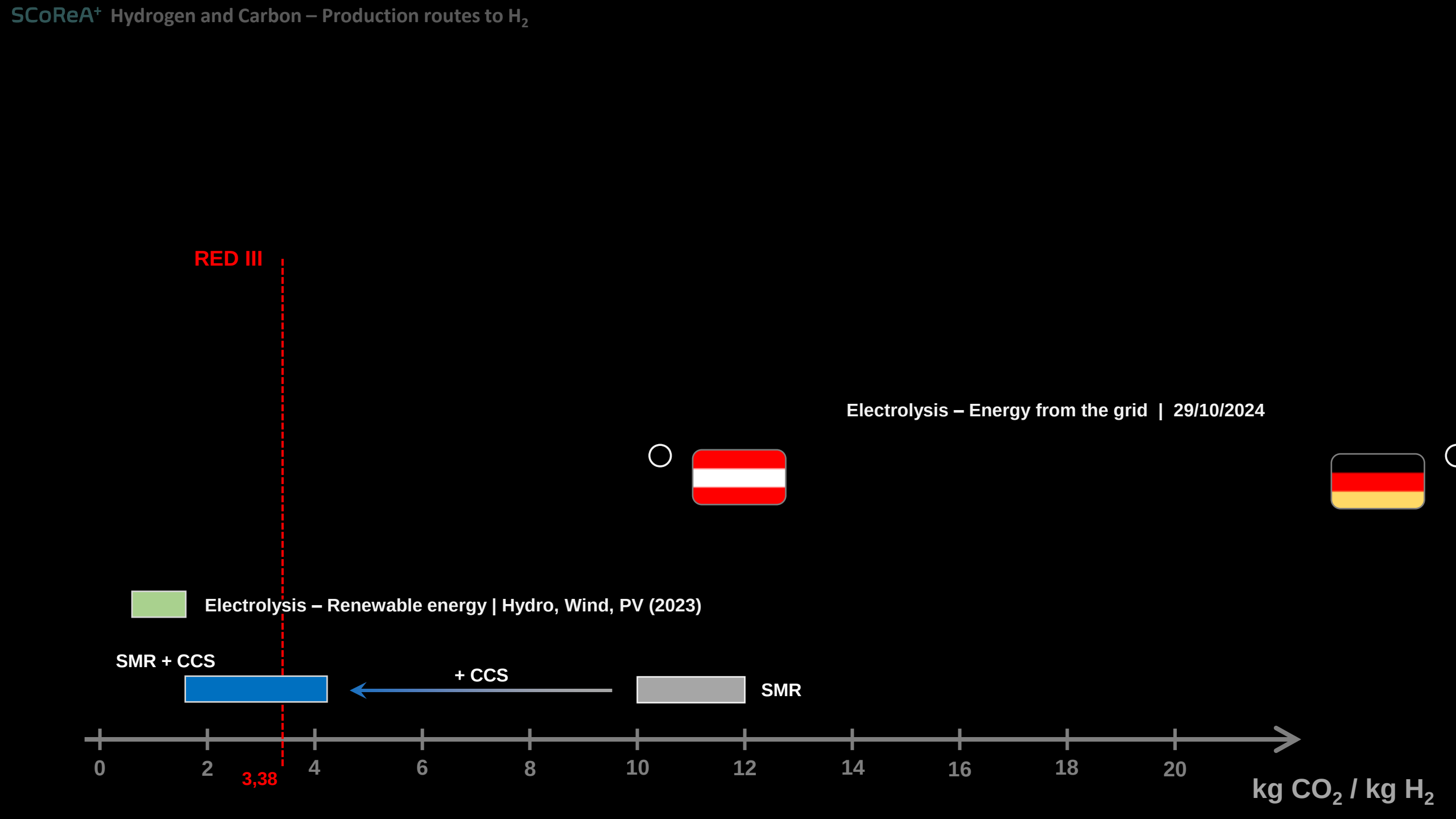
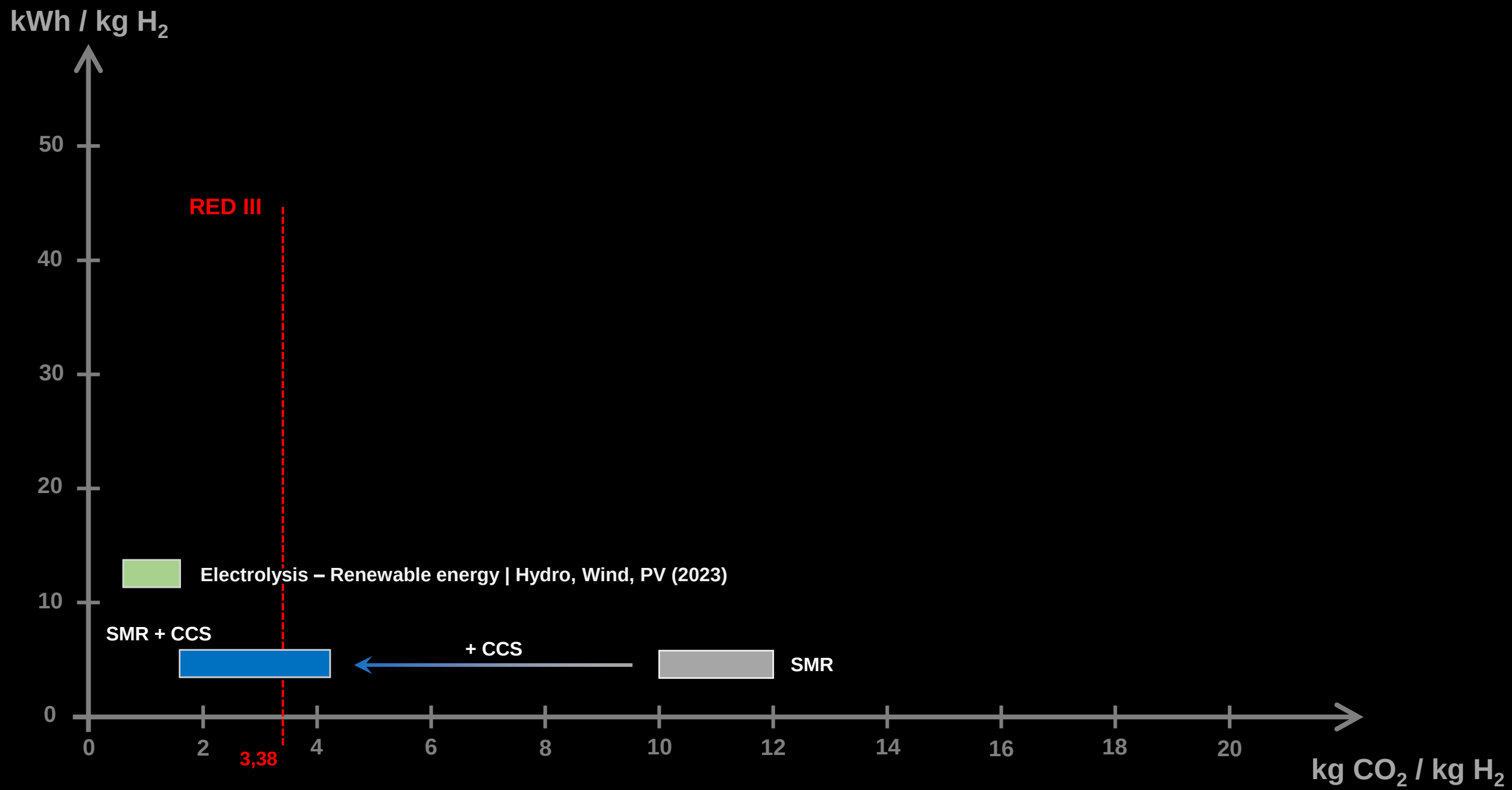
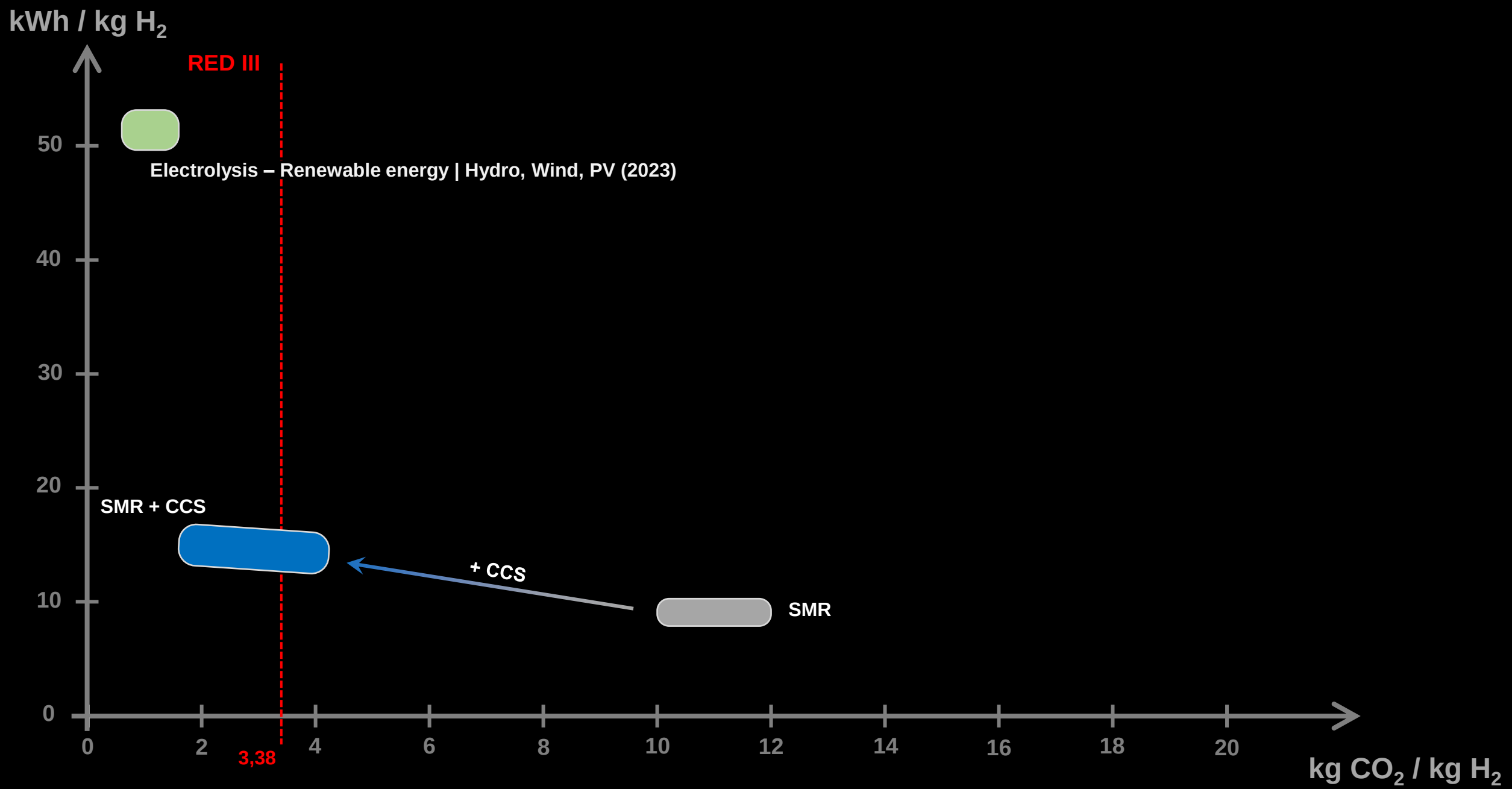

RED III
SMR
0
2
3,38
4
6
8
10
12
14
16
18
20
kg CO_2 / kg H_2

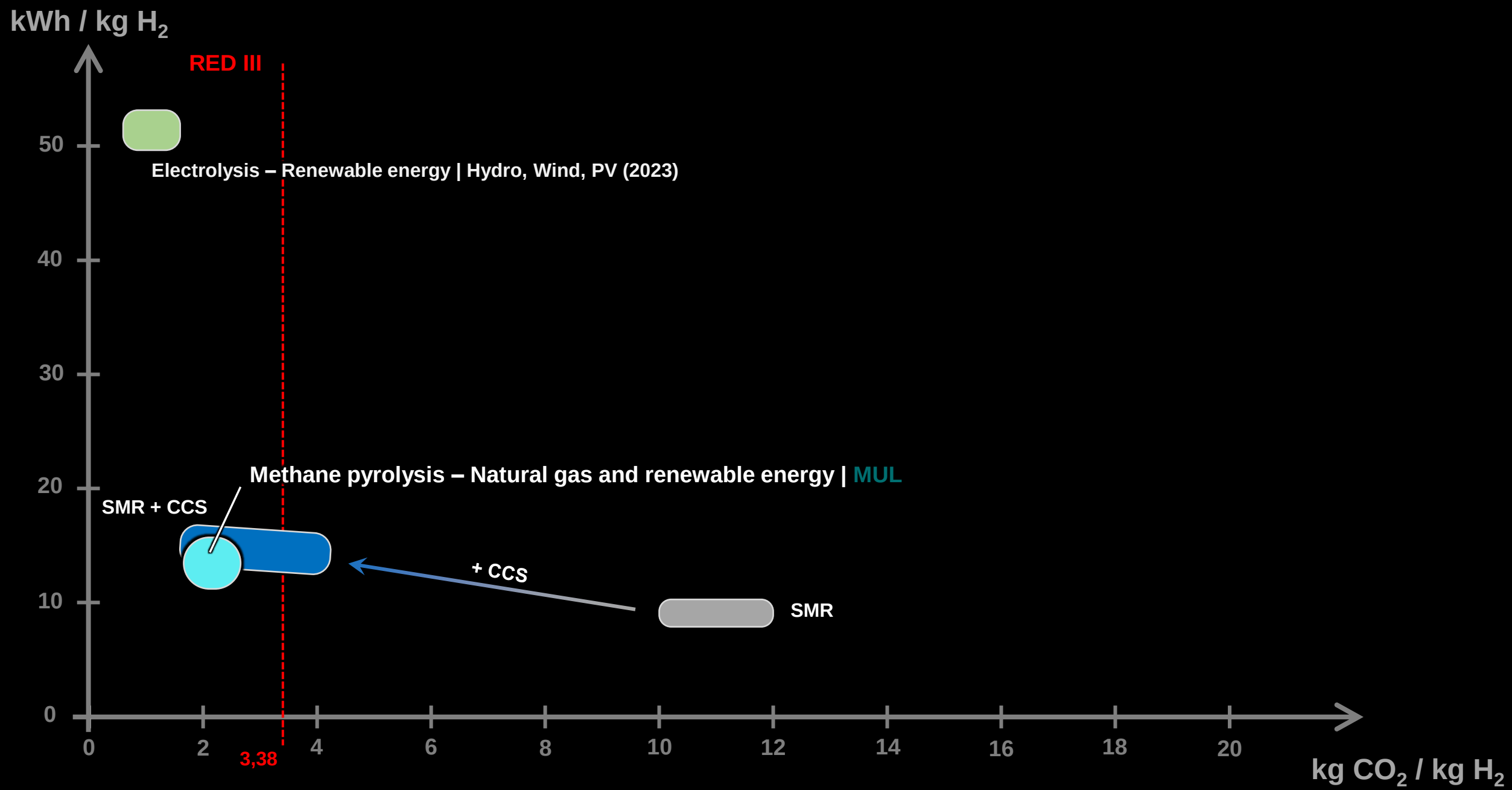

RED III
SMR + CCS
+ CCS
SMR
0
2
3,38
4
6
8
10
12
14
16
18
20
kg CO2 / kg H2


RED III
Electrolysis – Renewable energy | Hydro, Wind, PV (2023)
SMR + CCS
+ CCS
SMR
0
2
3,38
4
6
8
10
12
14
16
18
20
kg CO2 / kg H2

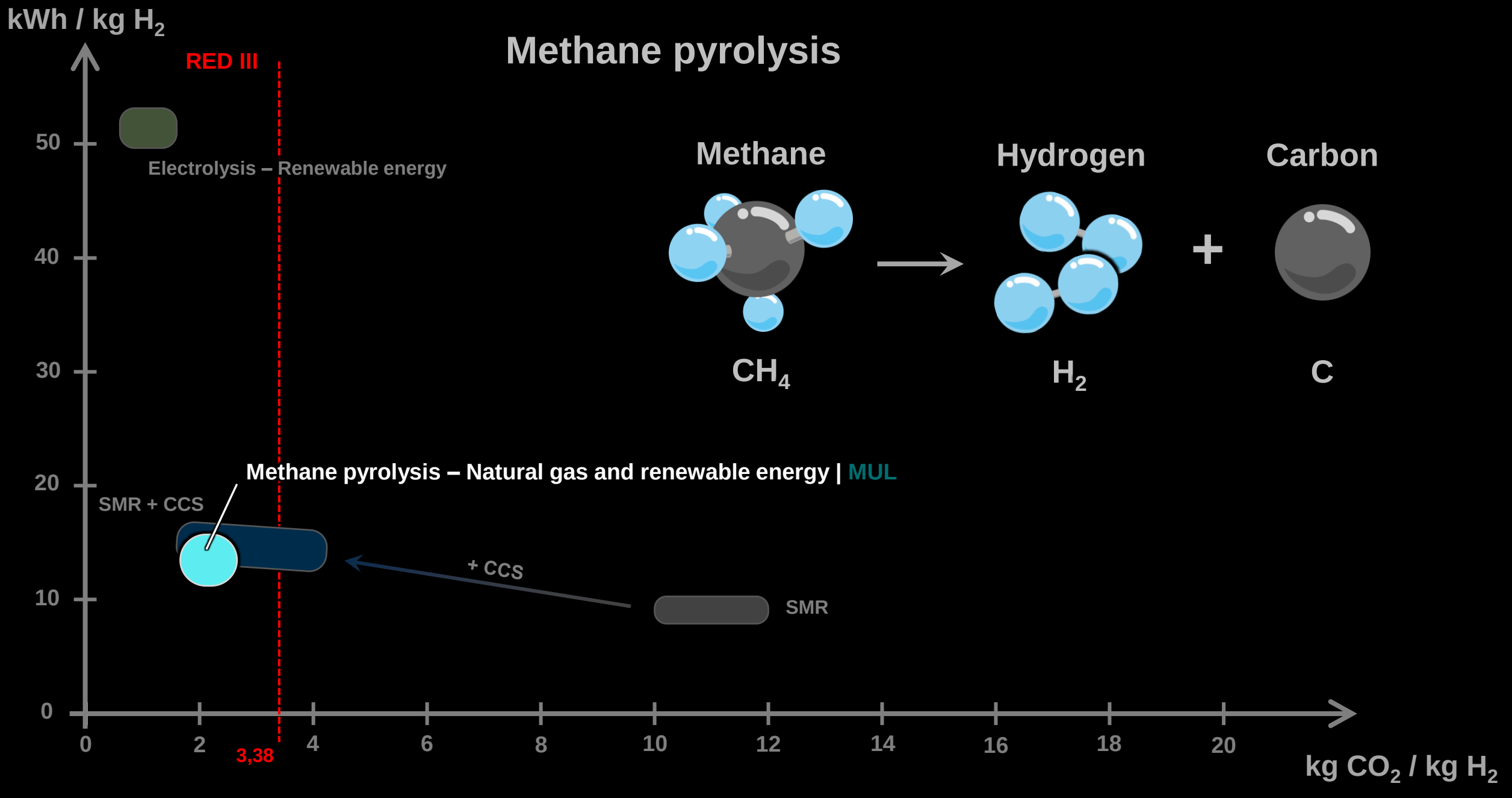

RED III
Electrolysis – Energy from the grid | 29/10/2024
Electrolysis – Renewable energy | Hydro, Wind, PV (2023)
SMR + CCS
+ CCS
SMR
0
2
3,38
4
6
8
10
12
14
16
18
20
kg CO2 / kg H2


kWh / kg H2
50
40
30
20
10
0
RED III
Electrolysis – Renewable energy | Hydro, Wind, PV (2023)
SMR + CCS
+ CCS
SMR
0
2
3,38
4
6
8
10
12
14
16
18
20
kg CO2 / kg H2

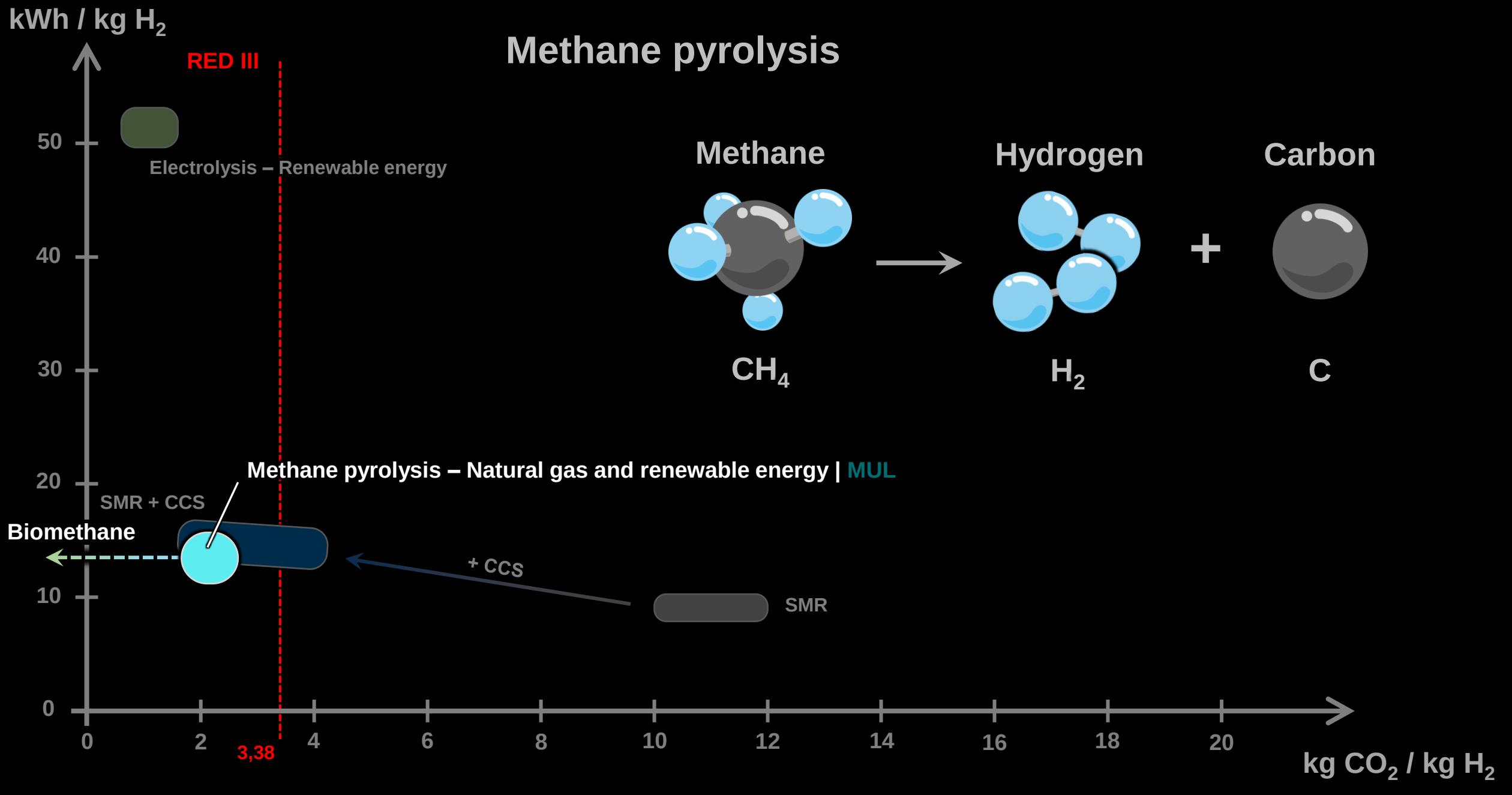

kWh / kg H2
RED III
50
40
30
20
10
0
Electrolysis – Renewable energy | Hydro, Wind, PV (2023)
SMR + CCS
+ CCS
SMR
0
2
3,38
4
6
8
10
12
14
16
18
20
kg CO2 / kg H2


kWh / kg H2
RED III
50
40
30
20
10
0
Electrolysis – Renewable energy | Hydro, Wind, PV (2023)
Methane pyrolysis – Natural gas and renewable energy | MUL
SMR + CCS
+ CCS
SMR
0
2
3,38
4
6
8
10
12
14
16
18
20
kg CO2 / kg H2

Methane pyrolysis



Methane pyrolysis



Electrolysis

kWh / kg H_2

RED III

Electrolysis – Renewable energy

Methane pyrolysis

SMR + CCS

Biomethane

+ CCS

SMR

0 10 20 30 40 50

0 2 3,38 4 6 8 10 12 14 16 18 20

kg CO_2 / kg H_2

Electrolysis

Pyrolysis

kWh / kg H_2

RED III

Electrolysis – Renewable energy

Methane pyrolysis

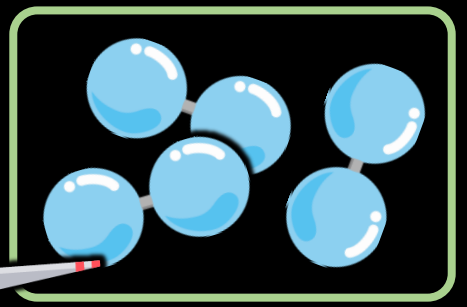
SMR + CCS

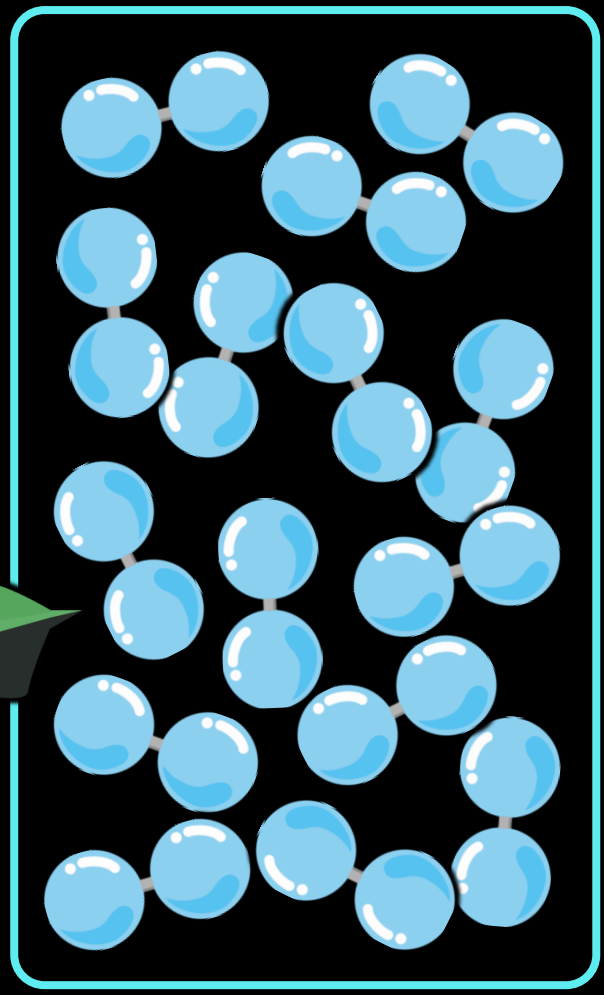
Biomethane

+ CCS

SMR

Fixed amount of renewable energy





50

40

30

20

10

0

0 2 3,38 4 6 8 10 12 14 16 18 20

kg CO_2 / kg H_2

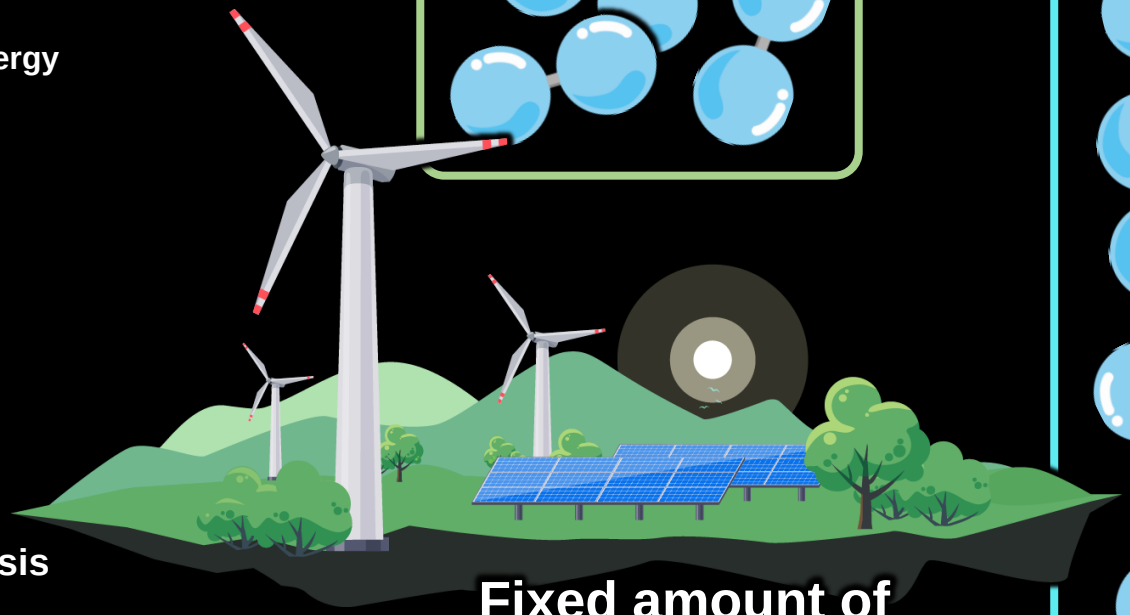
Electrolysis

Pyrolysis

kWh / kg H_2

RED III

Electrolysis – Renewable energy



Fixed amount of renewable energy

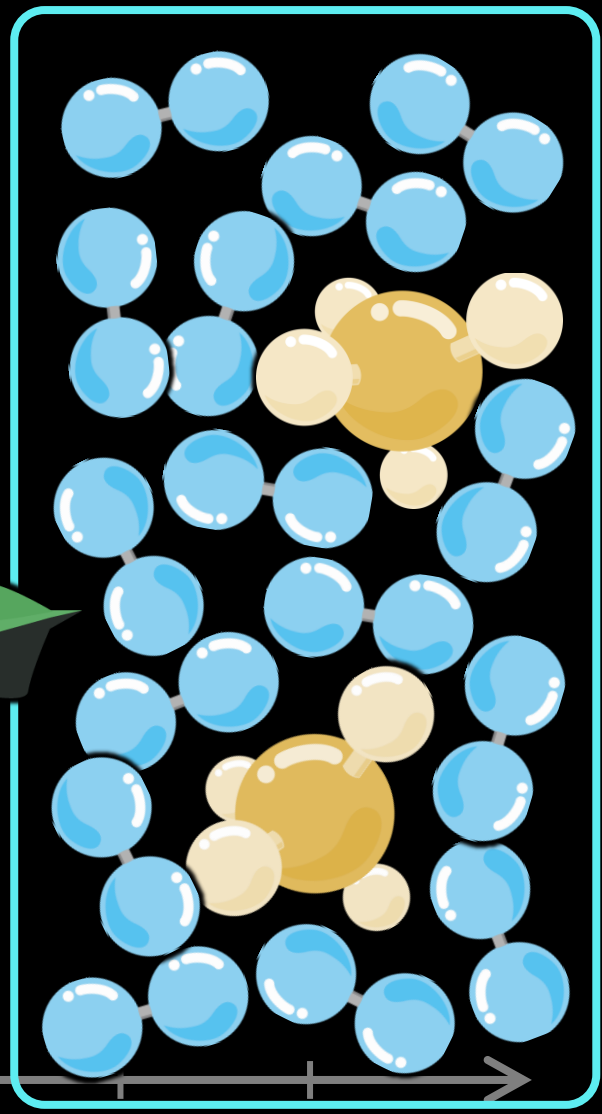
Methane pyrolysis

SMR + CCS

Biomethane

+ CCS

SMR



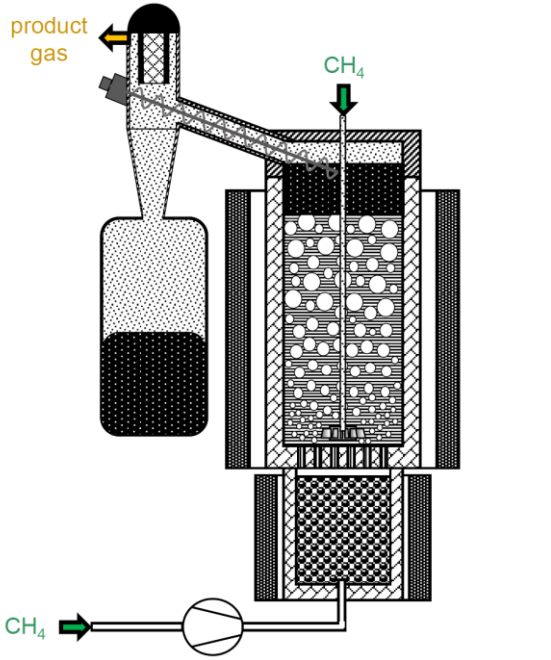
0 10 20 30 40 50

0 2 3,38 4 6 8 10 12 14 16 18 20

kg CO_2 / kg H_2

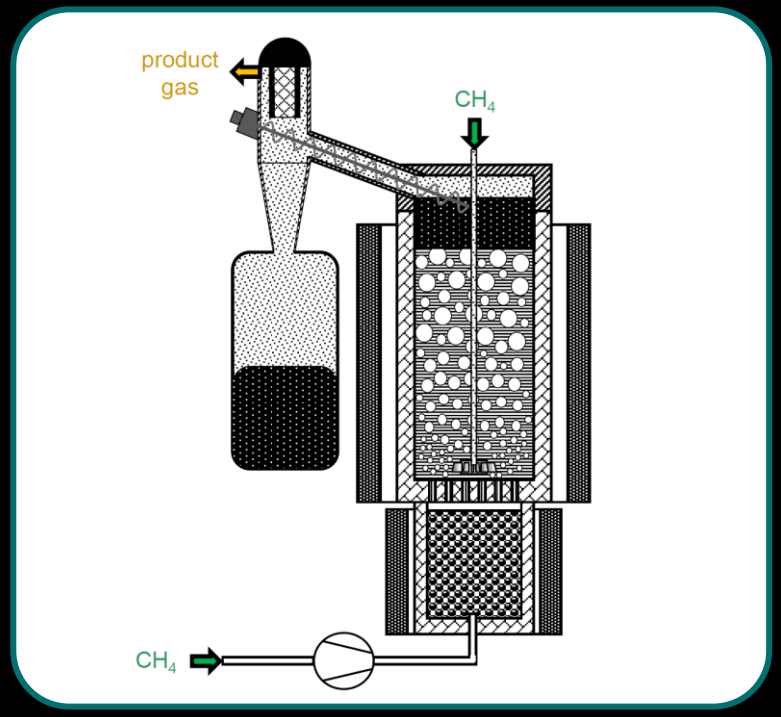
Hydrocarbon Pyrolysis

Hydrocarbon Pyrolysis

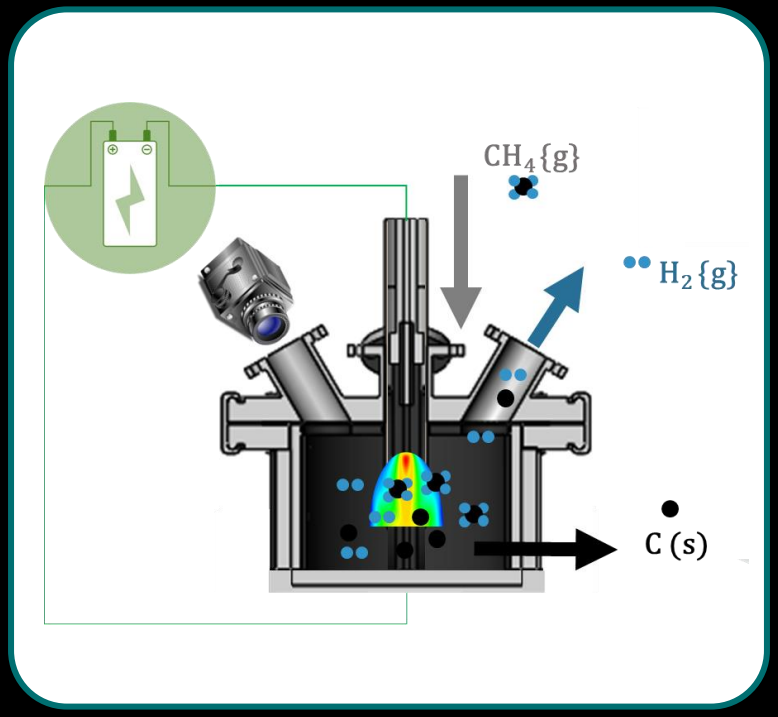


liquid metal /salt

Hydrocarbon Pyrolysis

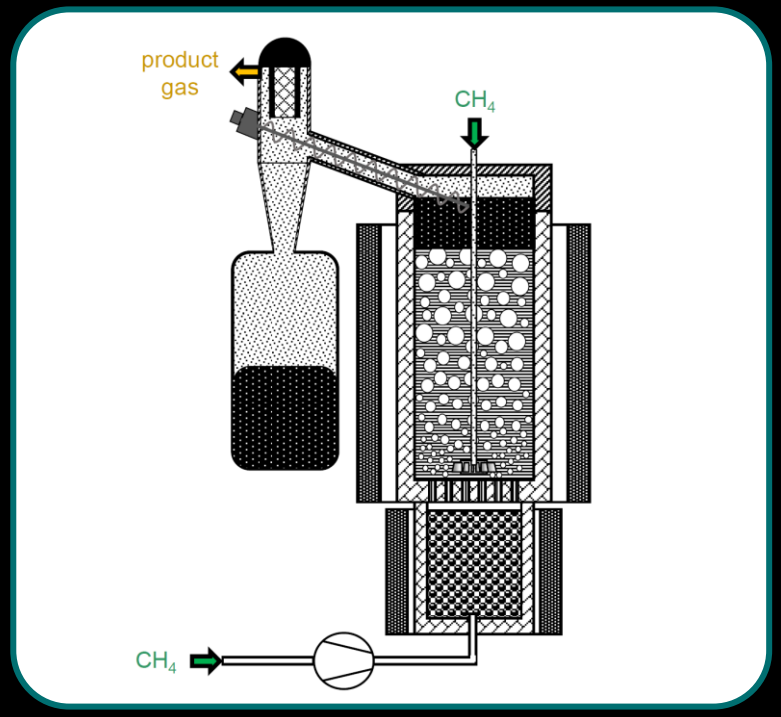


liquid metal /salt

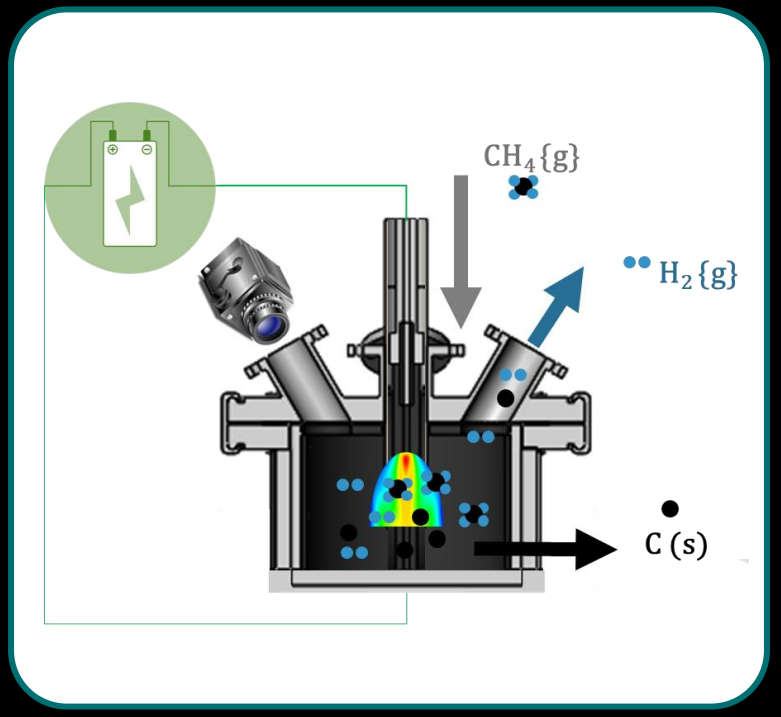


plasma

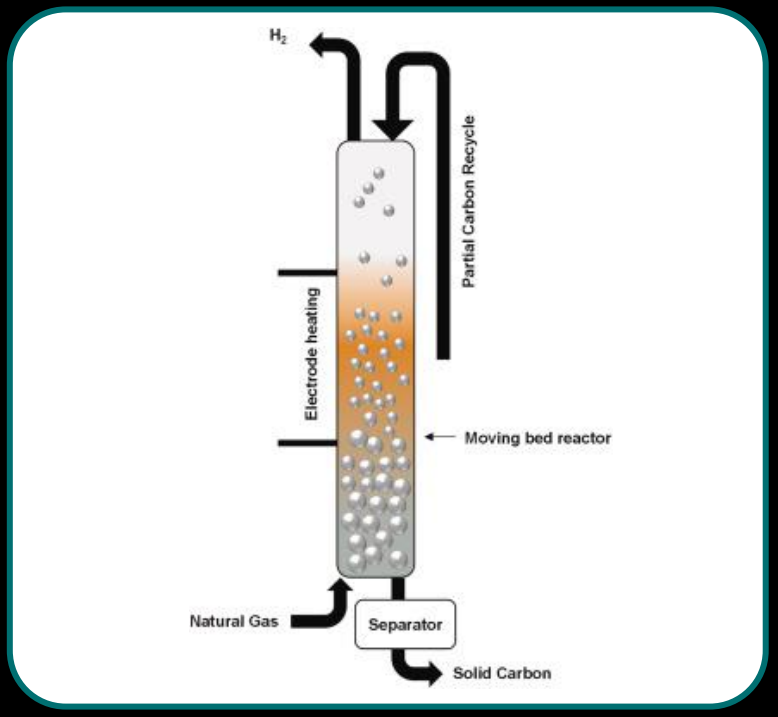
Hydrocarbon Pyrolysis



liquid metal /salt



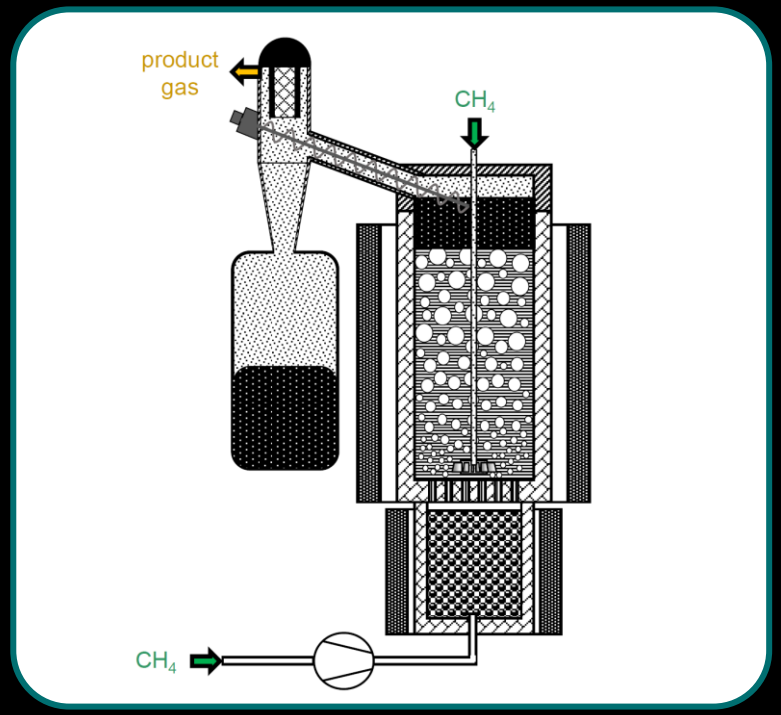
plasma



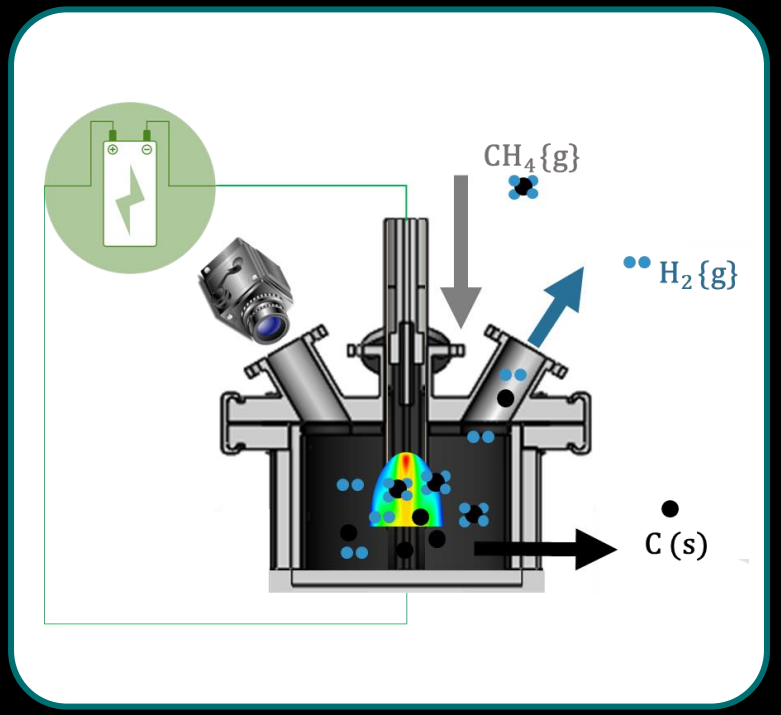
moving / fluidised bed

SCoRe A+
Strategic Core Research Area

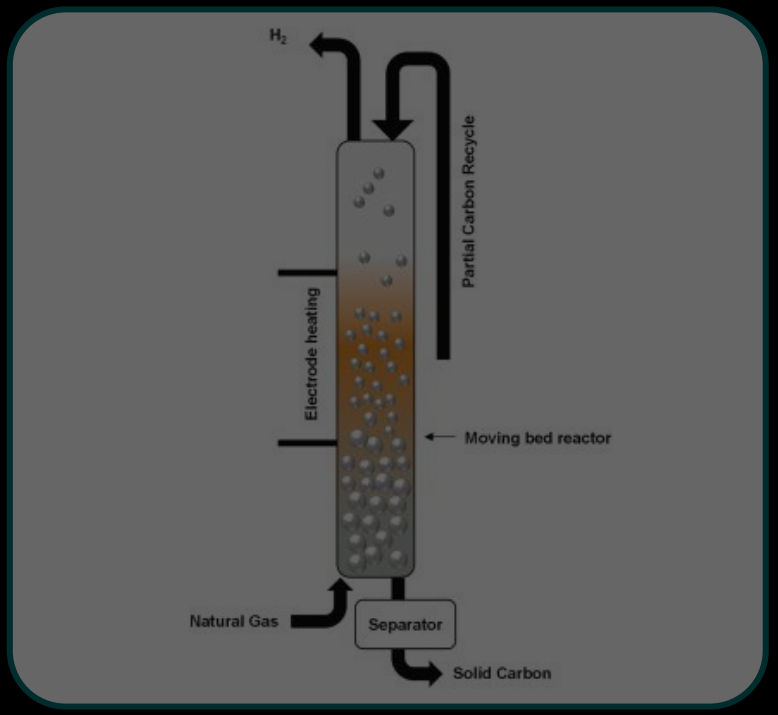
Hydrocarbon Pyrolysis



liquid metal /salt



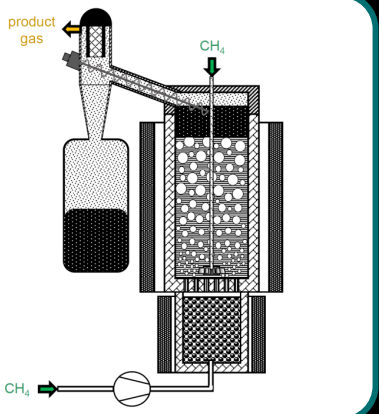
plasma



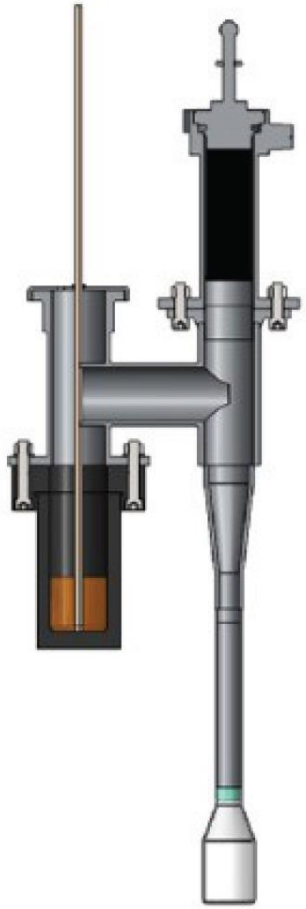
moving / fluidised bed

SCoRe A+
Strategic Core Research Area

Hydrocarbon Pyrolysis



liquid metal /salt



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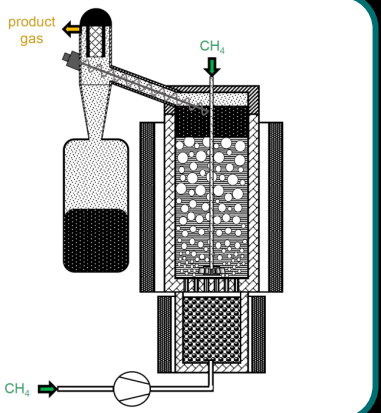
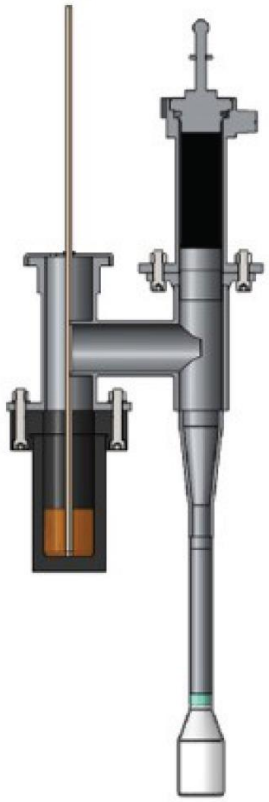
Strategic Core Research Area

Hydrocarbon Pyrolysis



liquid metal /salt

Reactor volume



0.25 dm³

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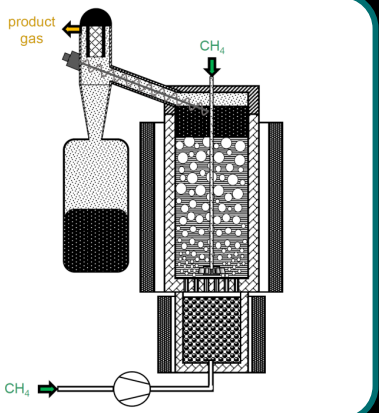
Strategic Core Research Area

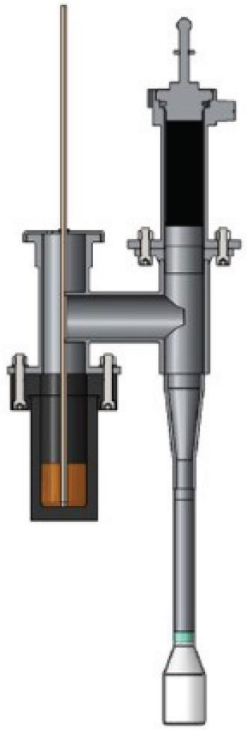
Hydrocarbon Pyrolysis



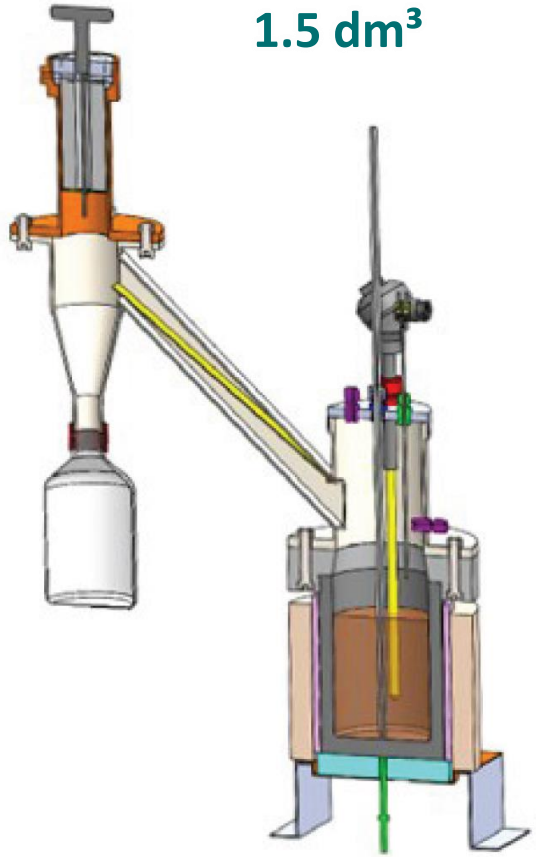
liquid metal /salt

Reactor volume

0.25 dm³

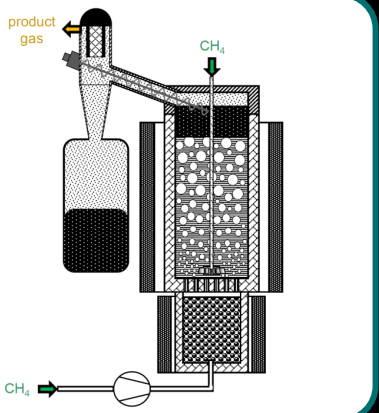


1.5 dm³



SCoRe A+
Strategic Core Research Area

Hydrocarbon Pyrolysis



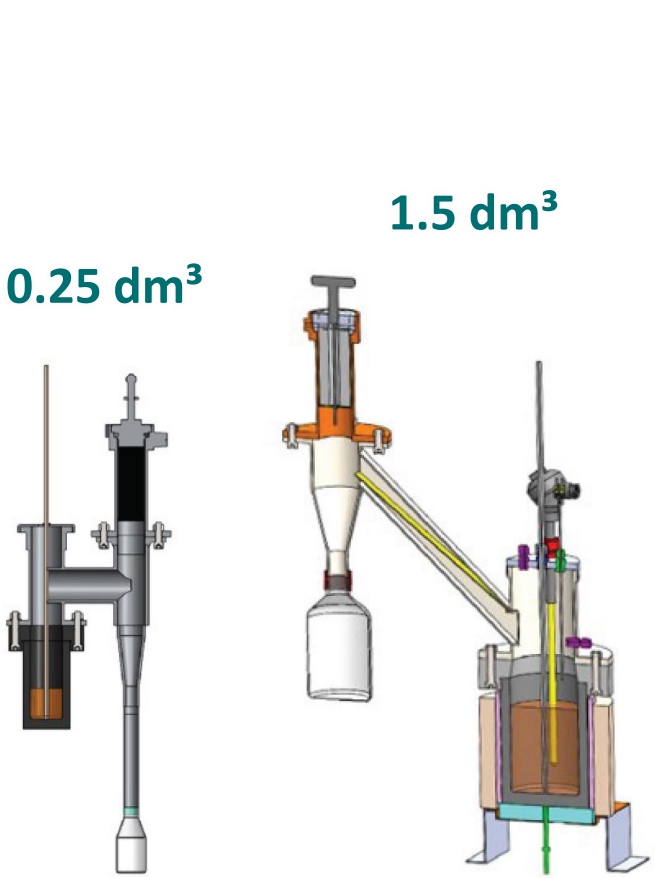
liquid metal /salt

Reactor volume

0.25 dm³

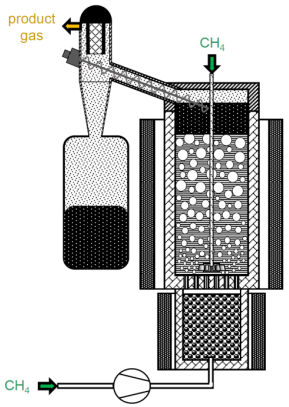
1.5 dm³

3.3 dm³



SCoRe A+
Strategic Core Research Area

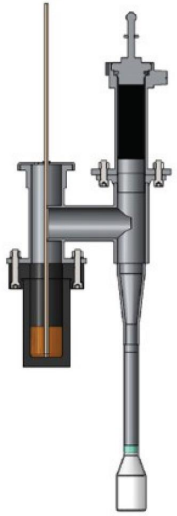
Hydrocarbon Pyrolysis



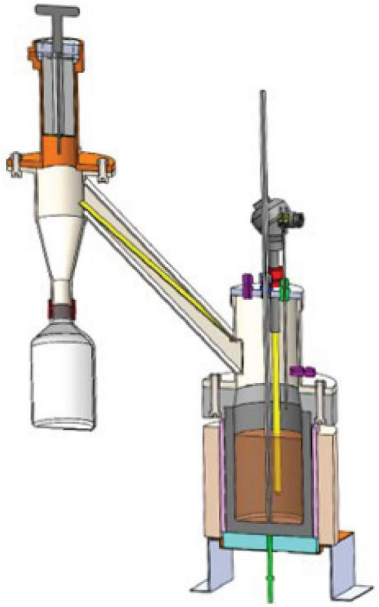
liquid metal /salt

Reactor volume

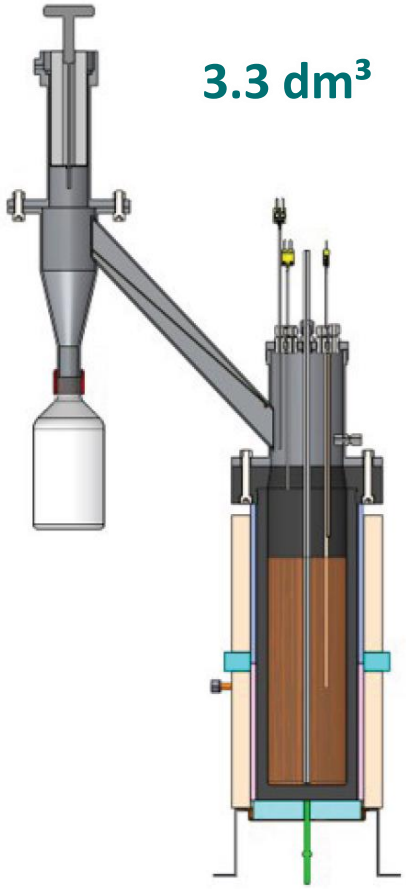
0.25 dm³



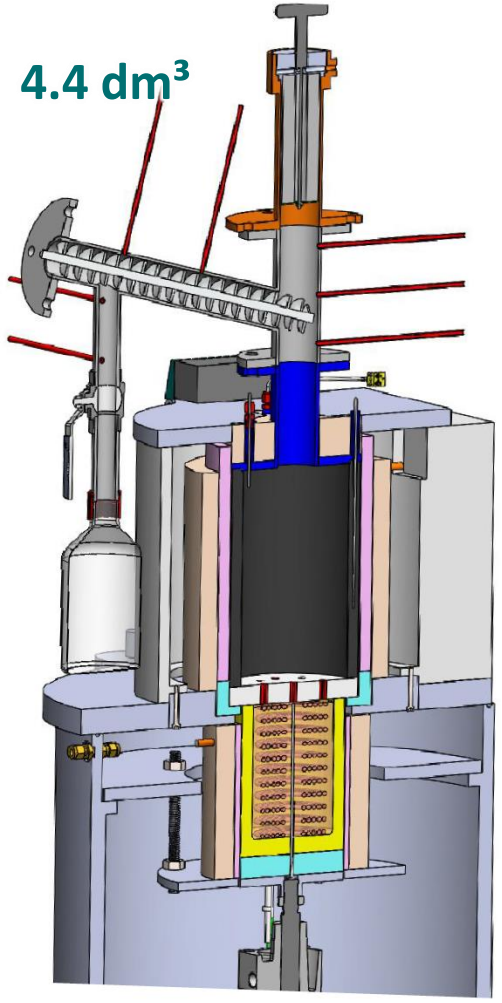
1.5 dm³



3.3 dm³

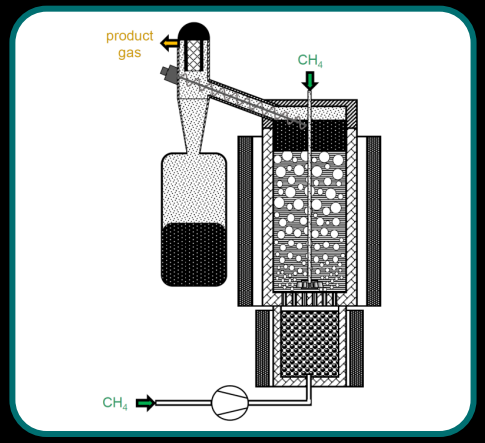


4.4 dm³



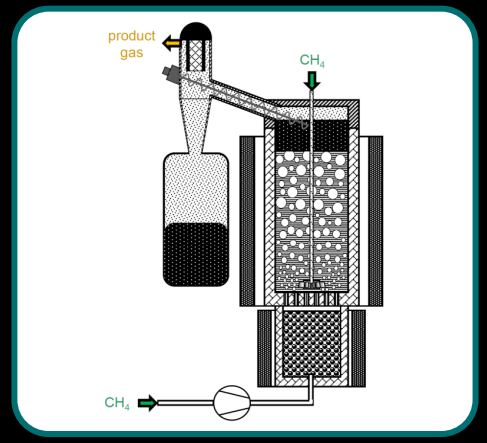
SCoRe A+
Strategic Core Research Area

Hydrocarbon Pyrolysis



SCoRe A+
Strategic Core Research Area

Hydrocarbon Pyrolysis



Fossile Fuels

Renewable Sources

Hydrogen 1 g 1 H 1.008 2.11

Hydrogen production

Feedstock

Hydrogen use

Hydrogen 1 g 1 H 1.008 2.11

Energy carrier (directly)

Synthetic energy carriers

Reduction agent

Conversion to electrical energy

Fossile Fuels

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Hydrogen 1 g 1 H 1.008 2.11

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Hydrogen transport
(conversion to other molecules)

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Gas conditioning

Materials science

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(conversion to other molecules)

Hydrogen storage

Small scale to large scale

Polymers, LOHCs, MeH-polymer hybrid, nanoporous Carbon

Underground storage systems

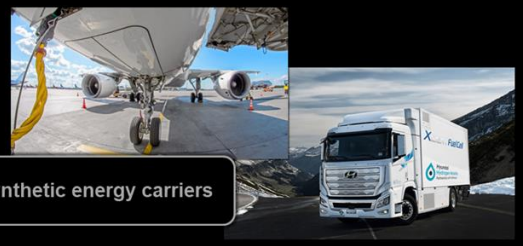
Hydrogen use

Hydrogen 1 g 1 H 1.008 2.11

Feedstock

Energy carrier (directly)

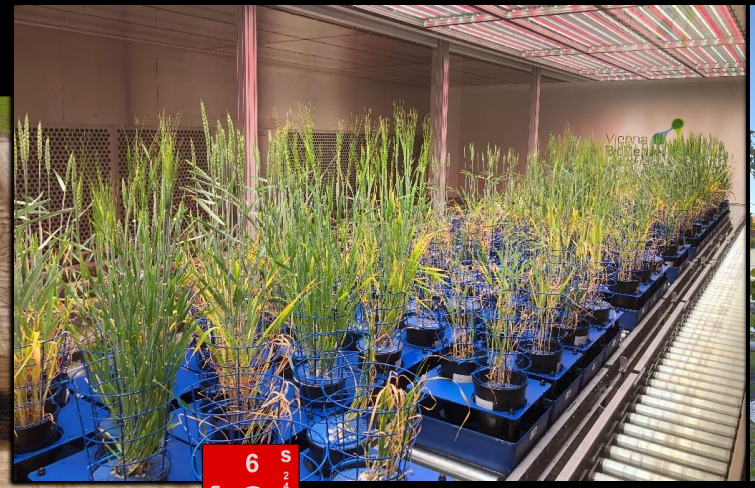
Synthetic energy carriers



Reduction agent

Conversion to electrical energy

SCoReA+ Hydrogen and Carbon – Overview



Carbon 6 C 12.01 (S 2 4, 2.06)

Fossil Fuels

Renewable Sources

Hydrogen 1 H 1.008 (g 1, 2.11)

Hydrogen production

Hydrogen transport (conversion to other molecules)

Hydrogen storage

Carbon 6 C 12.01 (S 2 4, 2.06)

- Gas conversion
- Gas conditioning
- Materials science

- Small scale to large scale
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Feedstock

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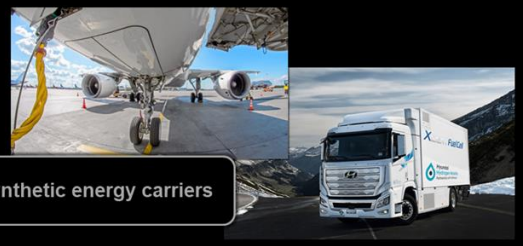

Synthetic energy carriers

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Carbon 6 C 12.01 (S 2 4, 2.06)

Conversion to electrical energy

Carbon 6 C 12.01 (S 2 4, 2.06)

SCoRe A+

Strategic Core Research Area

SCoRe A+
Strategic Core Research Area

Hydrogen production by
Methane Pyrolysis

Robert OBENAUS–EMLER

Head of Resouces Innovation Center
Coordinator of SCoRe A+ Hydrogen and Carbon

MONTAN UNIVERSITÄT LEOBEN

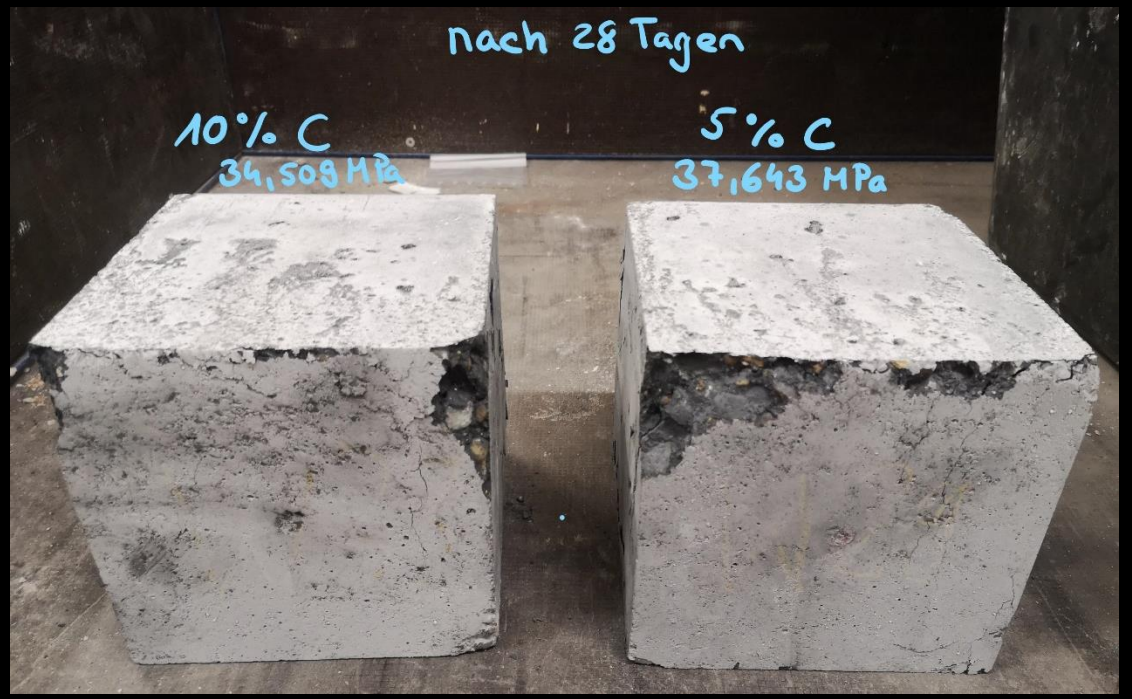
RIC Leoben

WHERE RESEARCH MEETS FUTURE

High volume applications of Carbon

(1) Construction industry

Insulation materials



Substitution of cement in concrete

High volume applications of Carbon

(2) Agriculture

Amazon basin

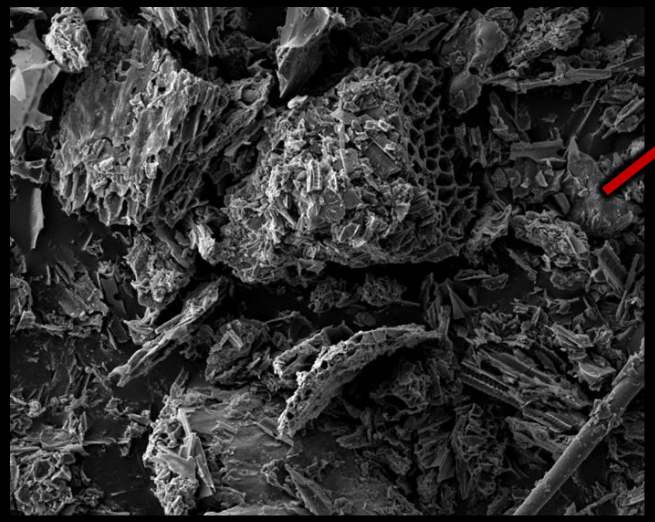
(450 BC – 950 AC)

High volume applications of Carbon

(2) Agriculture

Amazon basin

(450 BC – 950 AC)



Biochar

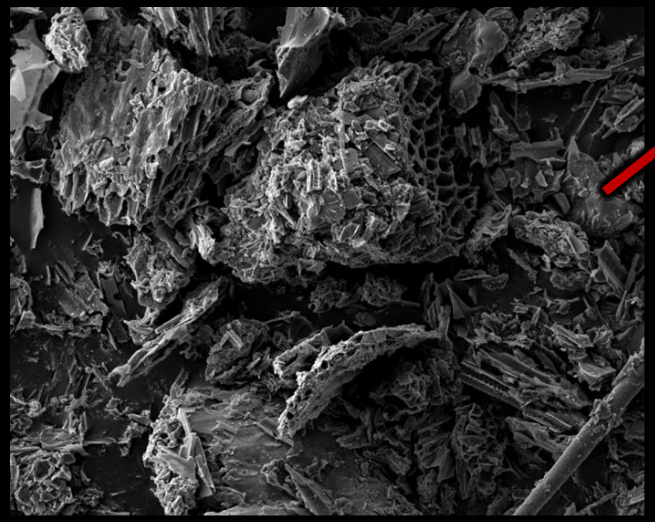
Terra preta soils

High volume applications of Carbon

(2) Agriculture

Amazon basin

(450 BC – 950 AC)



Biochar

Terra preta soils

- ☑ Water retention capacity
- ☑ Nutrient storage

High volume applications of Carbon

(2) Agriculture

Amazon basin

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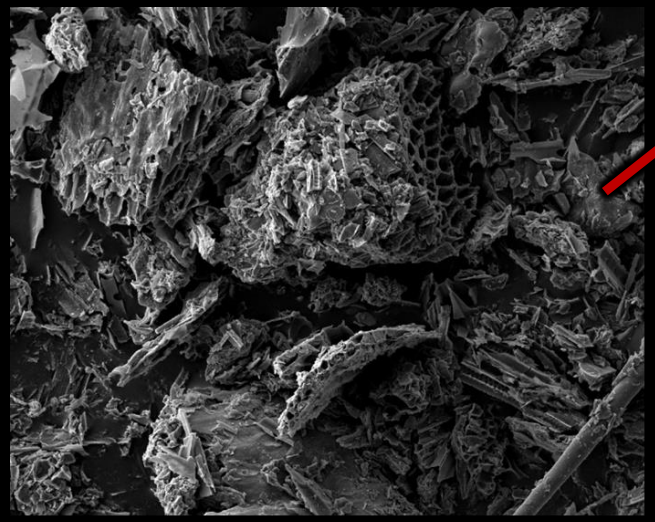

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Terra preta soils

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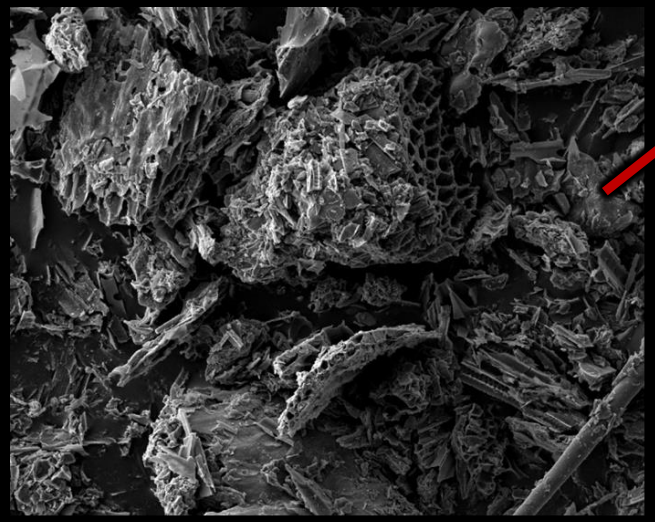

Biochar

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- ☑ Water retention capacity
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- ☑ Habitat for microorganisms
- ☑ Creation of humus

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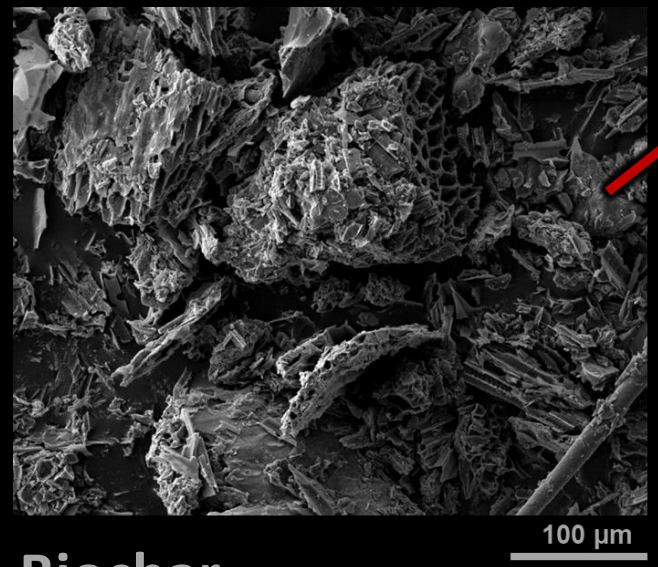
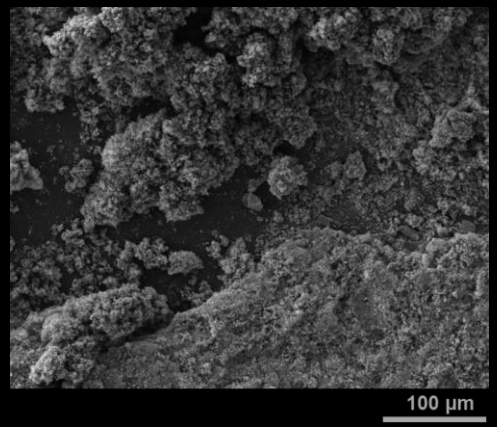


Biochar



Carbon from pyrolysis

Terra preta soils

- ☑ Water retention capacity
- ☑ Nutrient storage
- ☑ Habitat for microorganisms
- ☑ Creation of humus