BIO-HYDROGEN WITH CCUS (golden hydrogen) AS DECARBONISATION TOOL IN HARD-TO-ABATE INDUSTRIAL SECTORS. Application to tile sector in Spain

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13th National and 4th International Conference in Engineering Thermodynamics.

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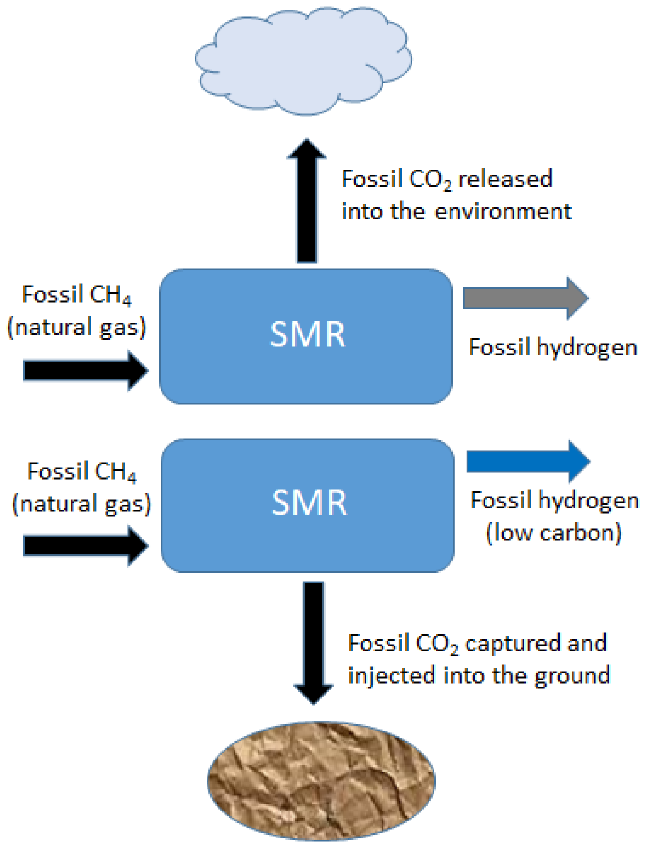
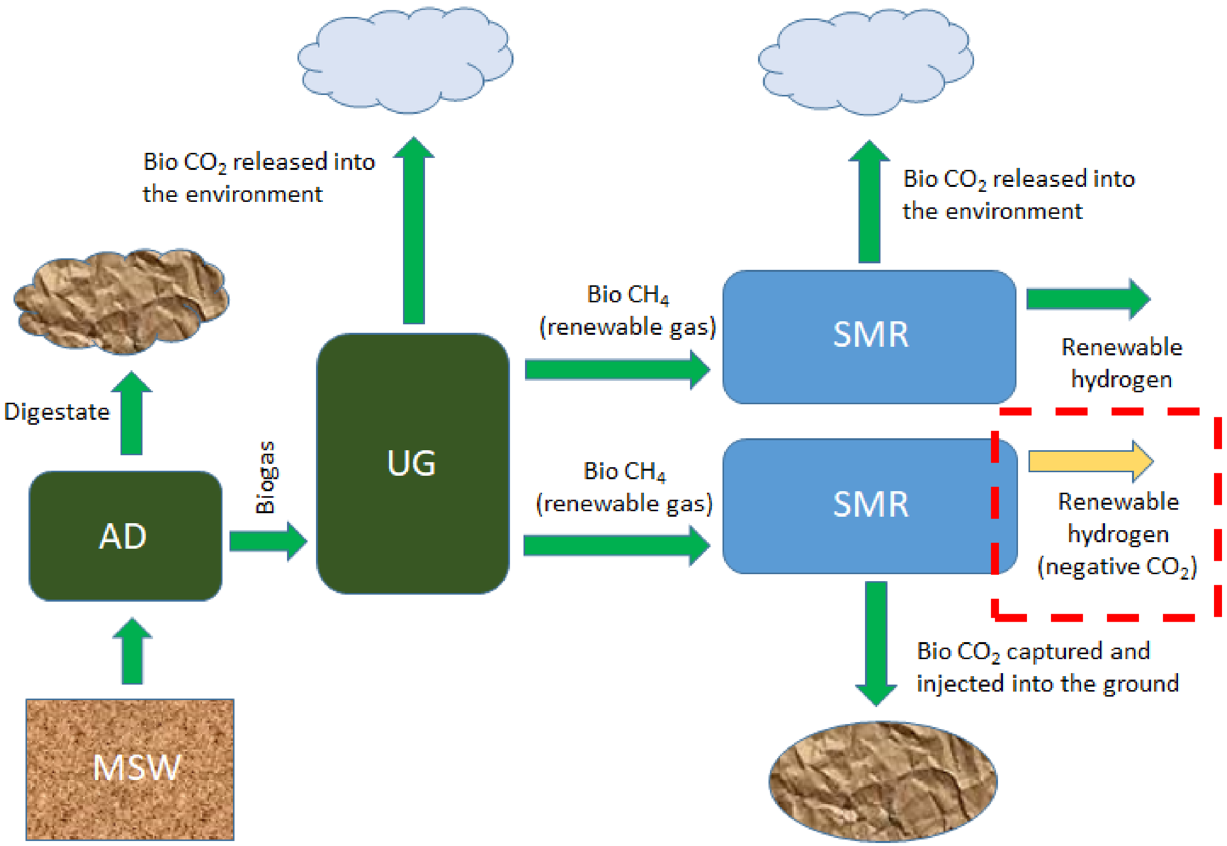
What is golden hydrogen ?

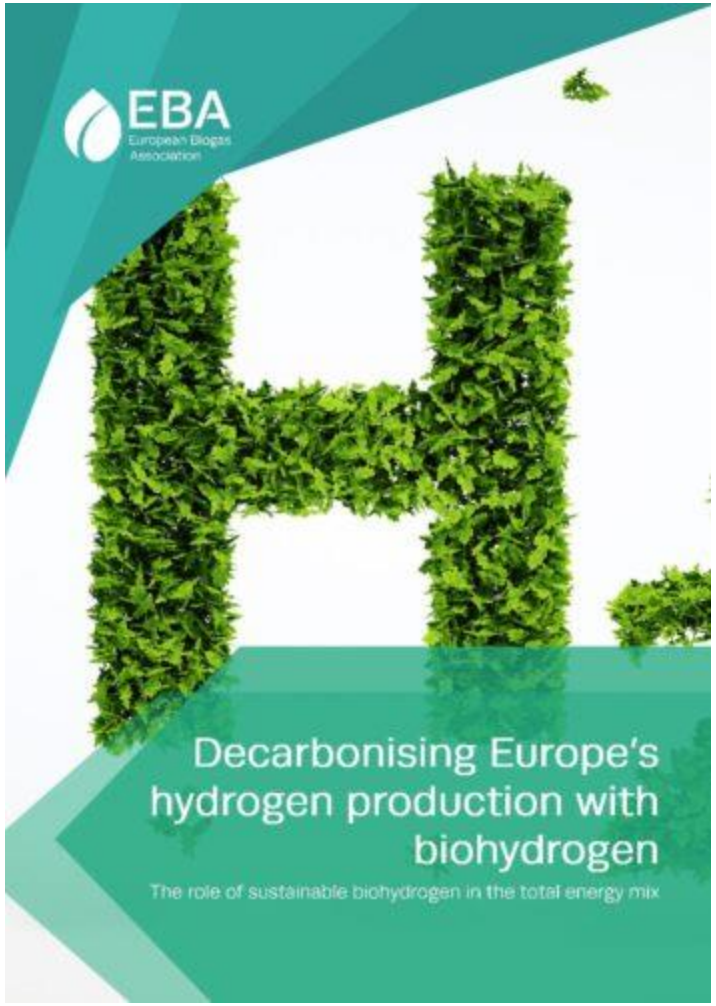


FOSSIL HYDROGEN



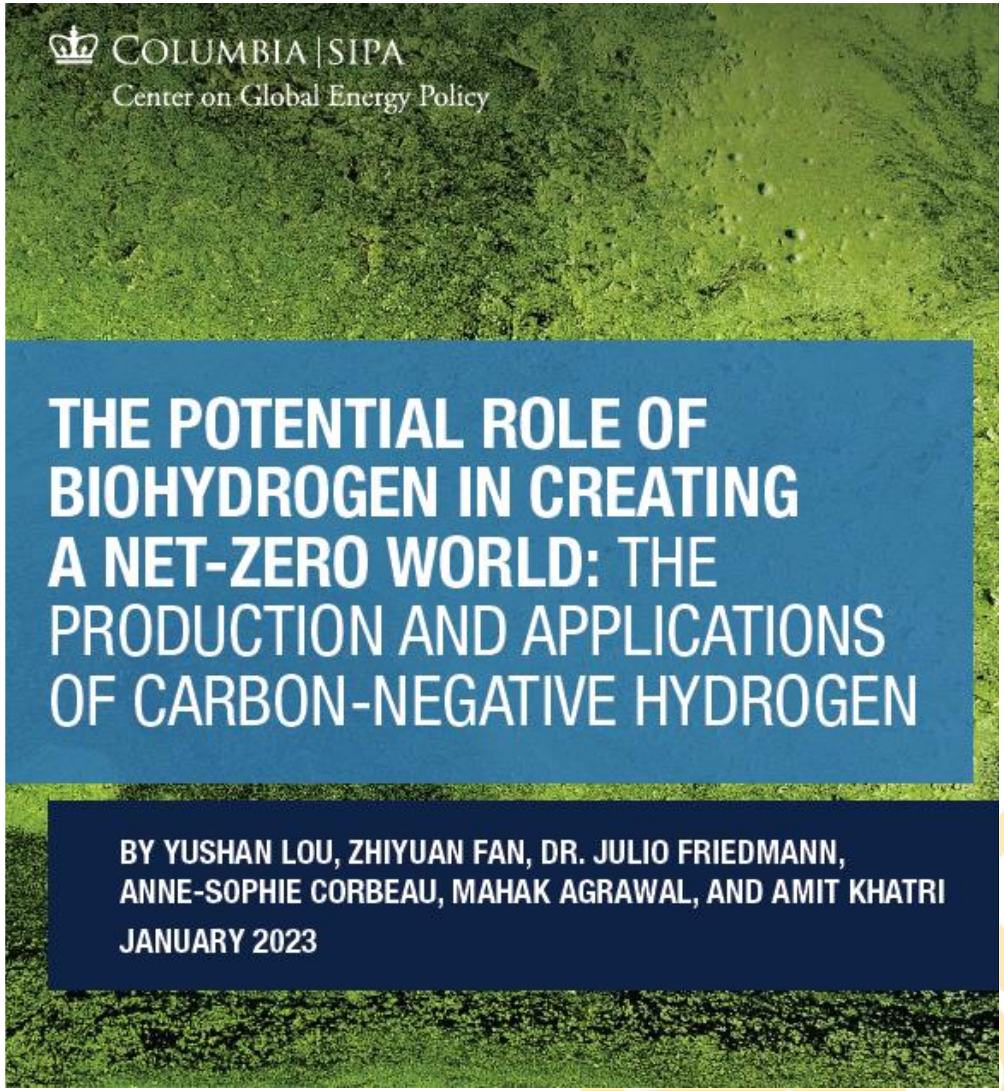
RENEWABLE HYDROGEN

International recognition



[EBA, 2023]

- SMR of bio-hydrogen releases biogenic CO_2
- CCS generates **negative emissions**
- Golden hydrogen **avoids** fossil emissions replacing fossil fuels AND **compensates** unavoided emissions of other sources



[COLUMBIA/SIPA, 2023]

Industrial experiences

Repsol produce hidrógeno a partir de biometano en una refinería española

UPSTREAM ONLINE / 05 OCTUBRE 2021

GAS

El hidrógeno se utilizará en la producción de combustibles como gasolina, gasóleo o queroseno para la aviación.

[Upstream Online, 5/10/2021]

[HARENSES, 2022]

- En Haro se va a producir hidrógeno por reformado de biogás

[HYGEAR, 2023]

> 200 t H2/year

CARBON NEGATIVE HYDROGEN AND BIOHYDROGEN

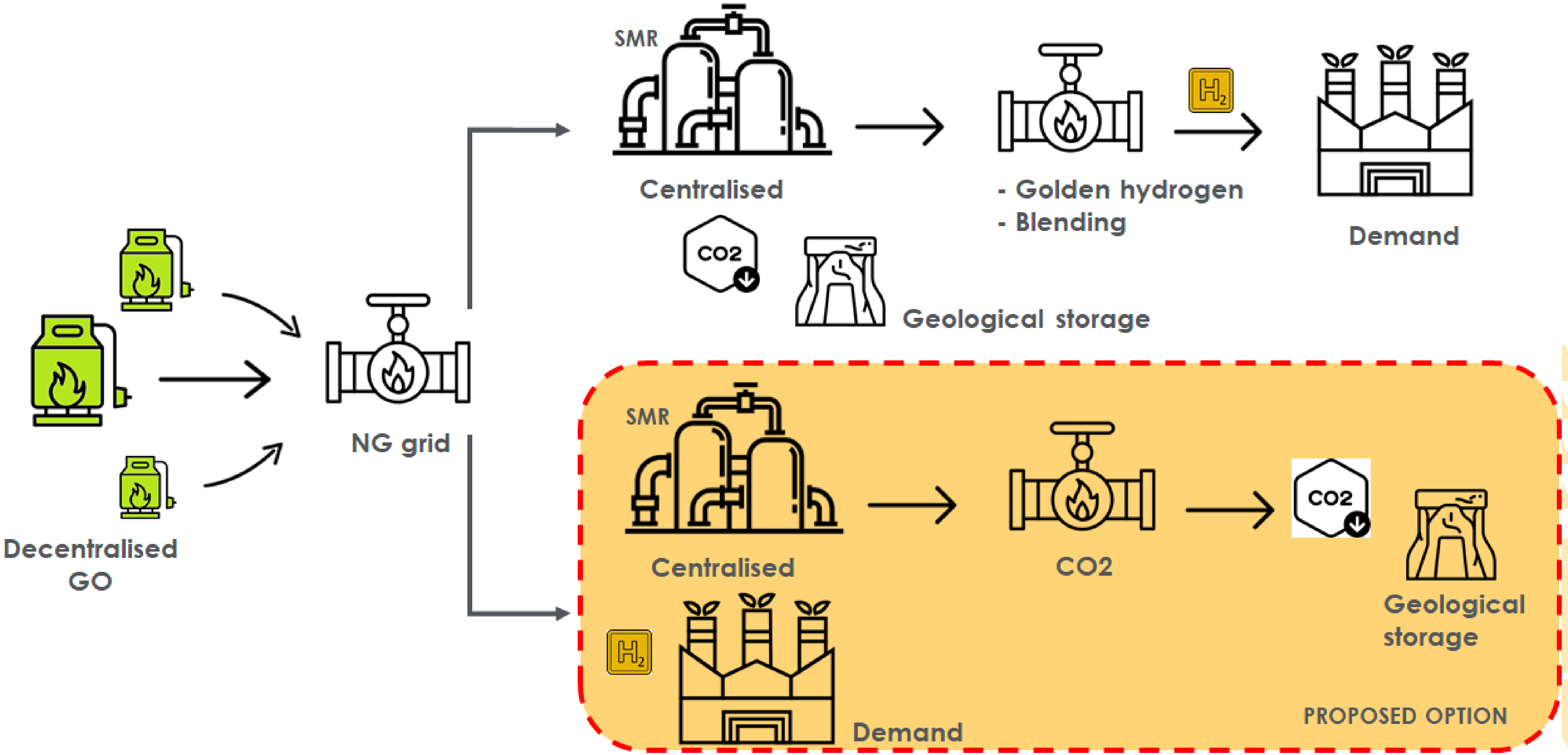
Producing (bio)hydrogen on-site using HyGear's Steam Methane Reforming (SMR) technology, and utilizing the hydrogen right where it is made, eliminates the need for transportation and the emissions that come with it. HyGear's hydrogen generators can work with renewable natural gas (RNG), also known as biomethane, derived from upgrading biogas that comes from biomass materials or organic residues, to produce hydrogen. In the case of on-site hydrogen production, this results in a carbon negative hydrogen or. When using biomethane to produce hydrogen this is also known as biohydrogen.

Performance

Table 1. Conversion ratios for SMR with or without CO_2 capture.

	η_{smr} p.u.	HMR $\frac{kmol\ H_2}{kmol\ CH_4}$	$CHMR$ $\frac{kg\ CO_2}{kg\ H_2}$	H2 production $\frac{t\ H_2}{GWh-HHV\ CH_4}$	Capture efficiency %	CO_2 captured $\frac{kg\ CO_2}{kg\ H_2}$
Without CCS	0.759	2.52	8.74	20.36	---	0
With CCS	0.691	2.29	0.96	18.54	90	8.64

Supply chain



Results. Blending 50/50 of golden hydrogen with natural gas

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$$LHV = \left(\frac{3\ kWh}{Nm^3}\right)\cdot 0.5 + \left(\frac{9.952\ kWh}{Nm^3}\right)\cdot 0.5 = 6.476\frac{kWh}{Nm^3} \Rightarrow 154.416\frac{Nm^3}{MWh\!-\!LHV}$$

$$\left(\frac{-8.64\ kg\ CO_2}{kg\ H_2}\right)\cdot\left(\frac{2\ kg\ H_2}{22.4 Nm^3}\right)\cdot 0.5 + \left(\frac{197.38\ kg\ CO_2}{MWh\!-\!LHV\ CH_4}\right)\cdot\left(\frac{9.952\cdot 10^{-3}\ MWh}{Nm^3\ CH_4}\right)\cdot 0.5 = 0.5965\ \frac{kg\ CO_2}{Nm^3\ blend}$$

50/50 is a future goal. It is used as higher limit of biomethane consumption.

$$\underbrace{92.1\frac{kg\ CO_2}{MWh - LHV}}_{golden\ hydrogen}$$

$$\underbrace{151.7\frac{kg\ CO_2}{MWh - LHV}}_{green\ hydrogen}$$

$$1\ MWh \Rightarrow 154.416\ Nm^3 \begin{cases} 77.21\ Nm^3\ H_2 \Rightarrow 33.72 Nm^3\ bCH_4 \\ 77.21\ Nm^3\ fCH_4 \end{cases}$$

Results. Blending 53.3/46.7 of biomethane with natural gas

$$LHV = 9.952\frac{kWh}{Nm^3} \Rightarrow 100.48\frac{Nm^3}{MWh-LHV}$$

$$\underbrace{92.1\frac{kg\ CO_2}{MWh-LHV}}_{bCH_4/fCH_4}$$

$$\left(\frac{197.38\ kg\ CO_2}{MWh-LHV\ CH_4}\right)\cdot\left(\frac{9.952\cdot 10^{-3}\ MWh}{Nm^3\ CH_4}\right)\cdot 0.4667 = 0.9168\ \frac{kg\ CO_2}{Nm^3\ blend}$$

53.34% bCH_4 / 46.67% fCH_4

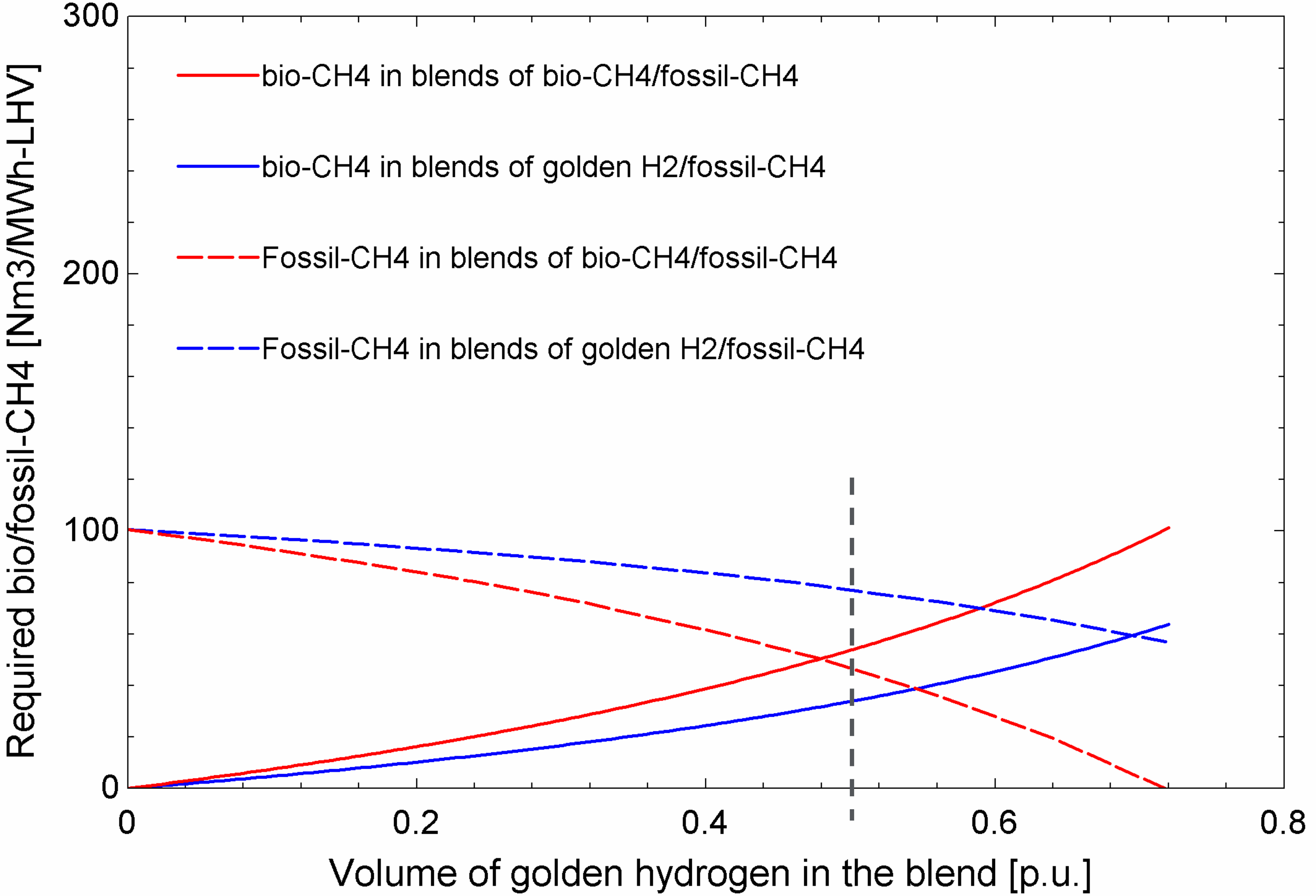
$$1\ MWh \Rightarrow 100.48\ Nm^3\ blend \begin{cases} 53.59\ Nm^3\ bCH_4 \\ 46.89\ Nm^3\ fCH_4 \end{cases}$$

50% gH_2 / 50% fCH_4

$$1\ MWh \Rightarrow 154.416\ Nm^3 \begin{cases} 77.21\ Nm^3\ H_2 \Rightarrow 33.72 Nm^3\ bCH_4 \\ 77.21\ Nm^3\ fCH_4 \end{cases}$$

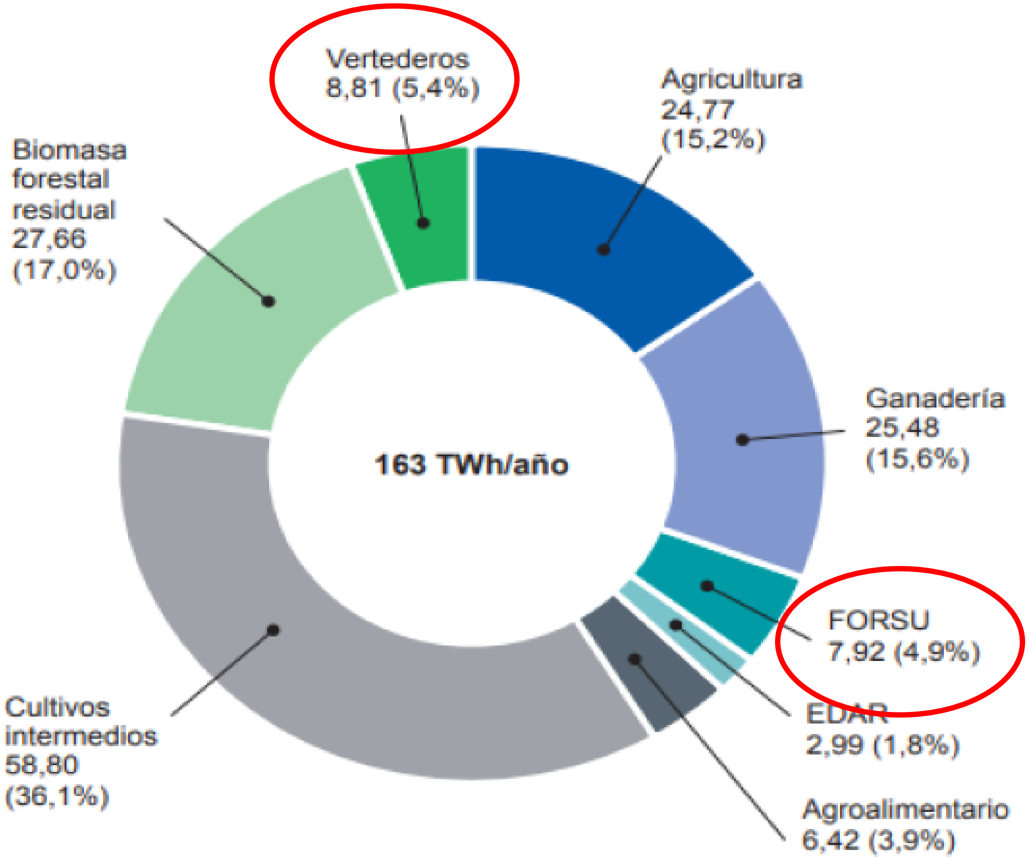
1 - 33.72 / 53.59 = 37% biomethane saving using golden hydrogen instead of directly biomethane

Results. Different levels of blending



Results. Tile sector

- Natural gas consumption in tile sector in Spain: 14 TWh
- 53.34% bCH_4 + 46.67% fCH_4
    - 8.28 TWh biomethane
    - 5.72 TWh natural gas
- 50% gH_2 + 50% fCH_4
    - 5.21 TWh biomethane (96.6 kt H_2)
    - 8.79 TWh natural gas

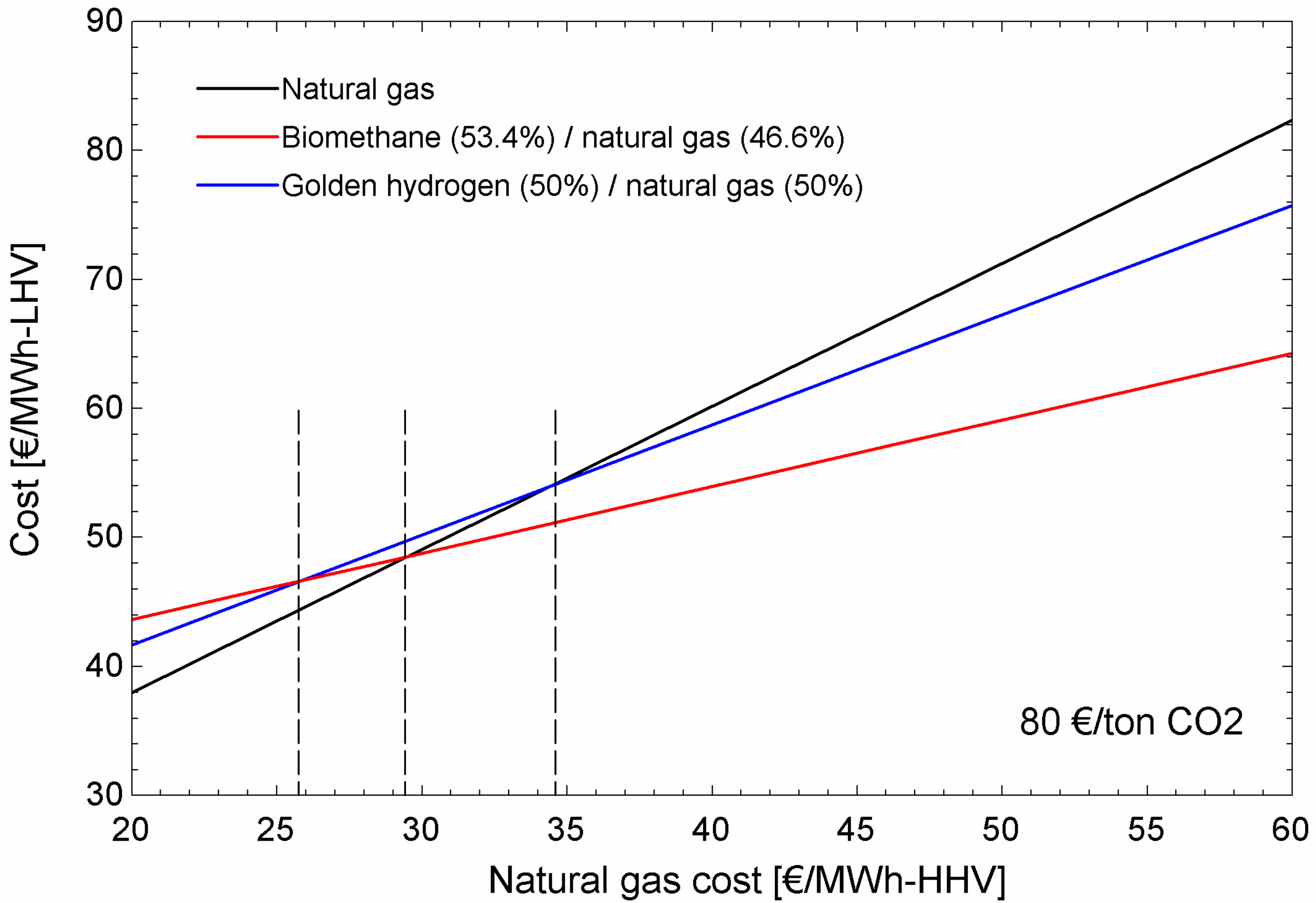


[SEDIGAS, 2023]

Results. Costs with biomethane from MSW

Source of biomethane: MSW

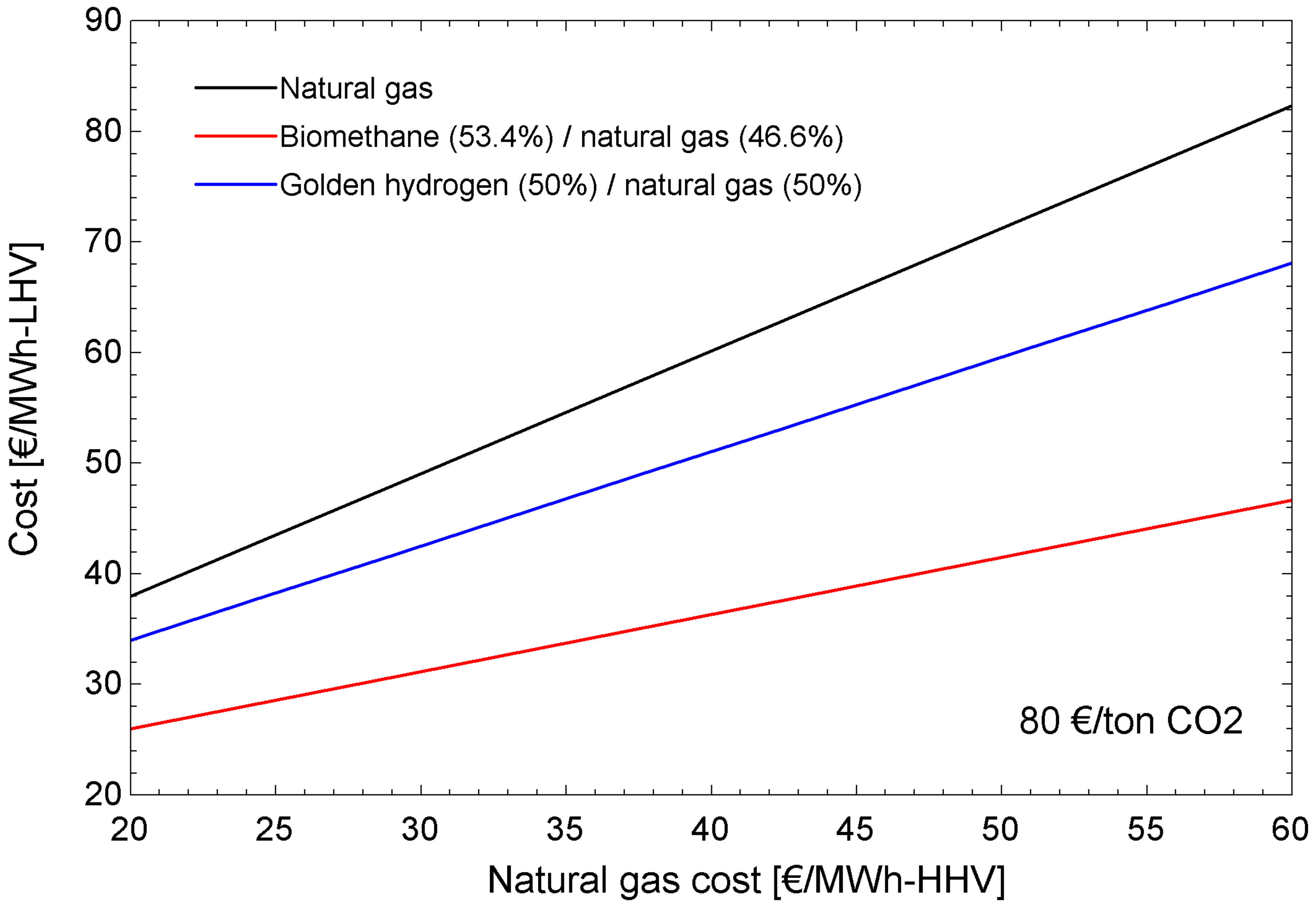
- LCOH (including carbon credits and CCS): 2 €/kg H2
- Biomethane: 44 €/MWh-HHV



Results. Costs with biomethane from landfill

Source of biomethane: landfill

- LCOH (including carbon credit and CCS): 0.7 €/kg H2
- Biomethane: 14 €/MWh-HHV



Conclusions

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- Bio-hydrogen with negative emissions (golden hydrogen) enables bio-methane savings
- Bio-methane is a limited resource:
  - Produced from de-gasification of landfills has a very low cost (14 €/MWh-HHV), translated into LCOH = 0.7 €/kg H2, but this resource is limited in time
  - Produced from organic fraction of MSW has a moderate cost (44 €/MWh-HHV), translated into LCOH = 2 €/kg H2, but it has continuous production
- Blending with golden hydrogen can be met from OFMSW for the entire tile Spain sector (34% available for other uses), but is not enough if direct biomethane is used

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THANKS FOR YOUR ATTENTION

Questions?

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