Italian National Agency for New Technologies,
Energy and Sustainable Economic Development

SolarFuelsNOW

Is there still room for steam reforming in the green hydrogen era?

Hydrogen and Beyond: How Solar Fuels and Chemicals Will Decarbonize the World

Cutting Edge R&D for the Solar Fuels of Tomorrow

November 23, 2021

Luca Turchetti – ENEA - Solar Thermal Energy and Smart Network Division

Did anybody say hydrogen?

Speech | 19 January 2021 | Brussels

Speech by President von der Leyen to the Hydrogen Council

The path towards a European hydrogen eco-system step by step :

Today - 2024	2025 - 2030	2030 -
From now to 2024, we will support the **installation of at least 6GW of renewable hydrogen electrolysers in the EU**, and the production of **up to 1 million tonnes** of renewable hydrogen.	From 2025 to 2030, hydrogen needs to **become an intrinsic part of our integrated energy system**, with at least 40GW of renewable hydrogen electrolysers and the production of **up to 10 million tonnes** of renewable hydrogen in the EU.	From 2030 onwards, **renewable hydrogen will be deployed at a large scale** across all hard-to-decarbonise sectors.

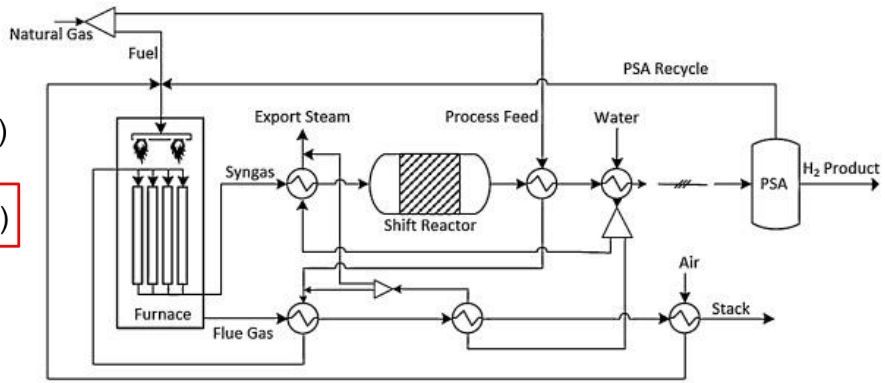
Grey hydrogen: business as usual

$$CH_4 + H_2O \leftrightarrows CO + 3H_2 \qquad \Delta H_{500°C} = 221{,}6 \ \frac{kJ}{mol} \qquad \text{(SR)}$$

$$CO + H_2O \leftrightarrows CO_2 + H_2 \qquad \Delta H_{500°C} = -37{,}4 \ \frac{kJ}{mol} \qquad \text{(WGS)}$$

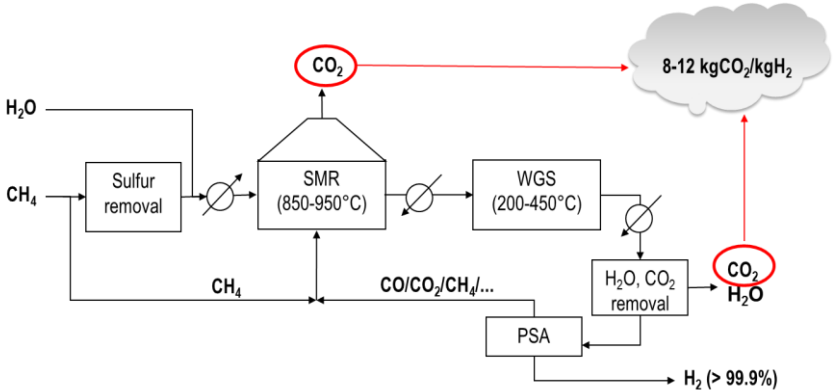
$$\boxed{CH_4 + 2H_2O \leftrightarrows CO_2 + 4H_2 \qquad \Delta H_{500°C} = 184{,}2 \ \frac{kJ}{mol} \qquad \text{(OSR)}}$$

$$CH_4 + CO_2 \leftrightarrows 2CO + 2H_2 \qquad \frac{kJ}{mol} \qquad \text{(DR)}$$

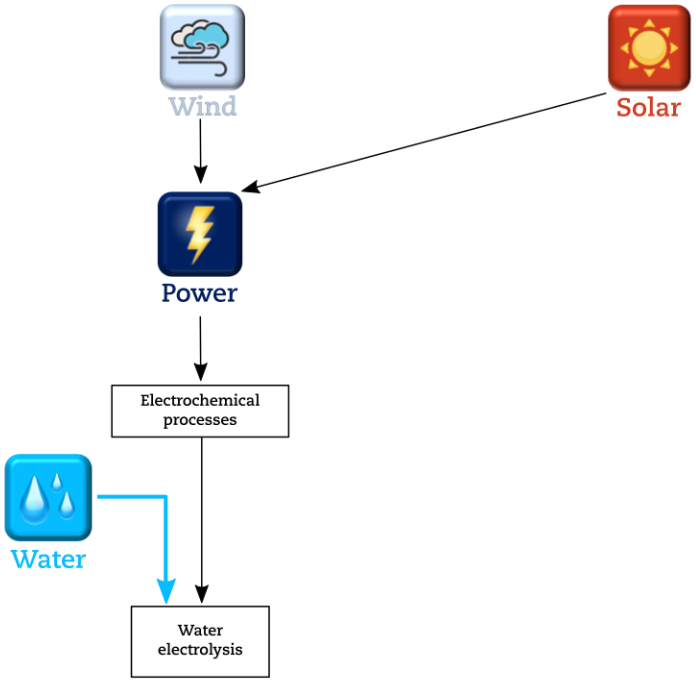


Conventional process:

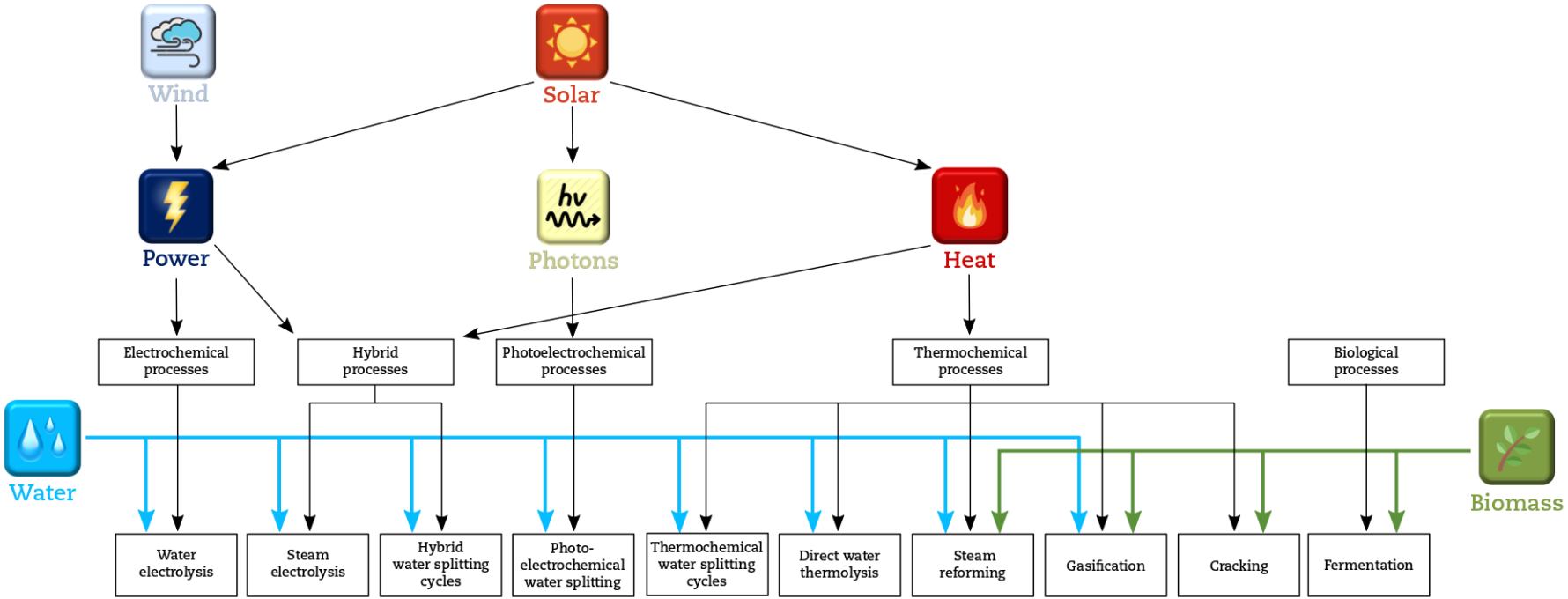
- Carried out in externally heated (furnace) tubular reactors
- Operating conditions: T = 700-1000 °C; P = 10-40 bar; S/C = 3-6
- Downstream of the reformer 1 or 2 WGS reactor(s) (500-600°C)
- Up to 12 t of CO_2 per t of H_2
    - From the chemical reaction
    - From combution
- H_2 production cost: 1-2 $/kg, strongly depending on gas price



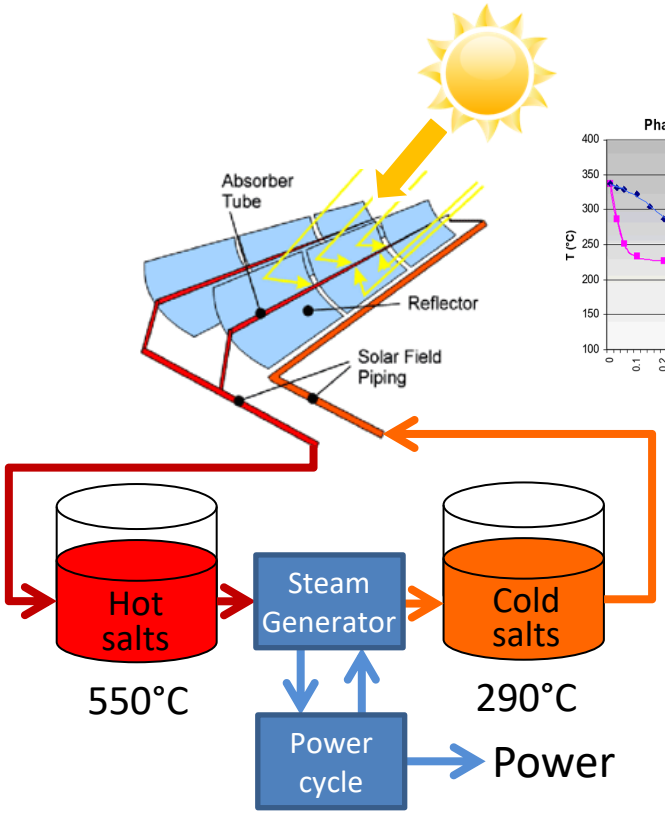
Green hydrogen production:

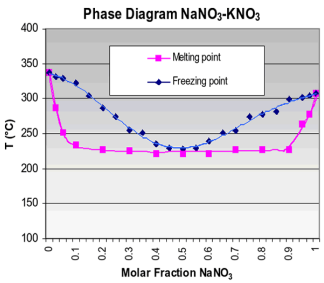


Green hydrogen production: much more than electrolysis!



ENEA's CST technology





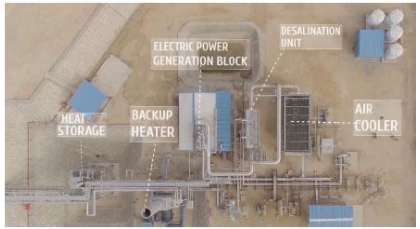
Since early 2000s ENEA has been developing an innovative CS technology:

- Concentration technology: Parabolic trough (PT) collectors
- *Solar Salt* (60% $NaNO_3$ 40% KNO_3) used both as:
  - heat transfer fluid
  - heat storage medium in a 2-tank direct TES system
- First 5 MW demo plant in 2010 (Italy)
- First cogenerative demo plant (1 MW_{el} + 250 m^3/d desalinated water) in 2018 (Egypt)

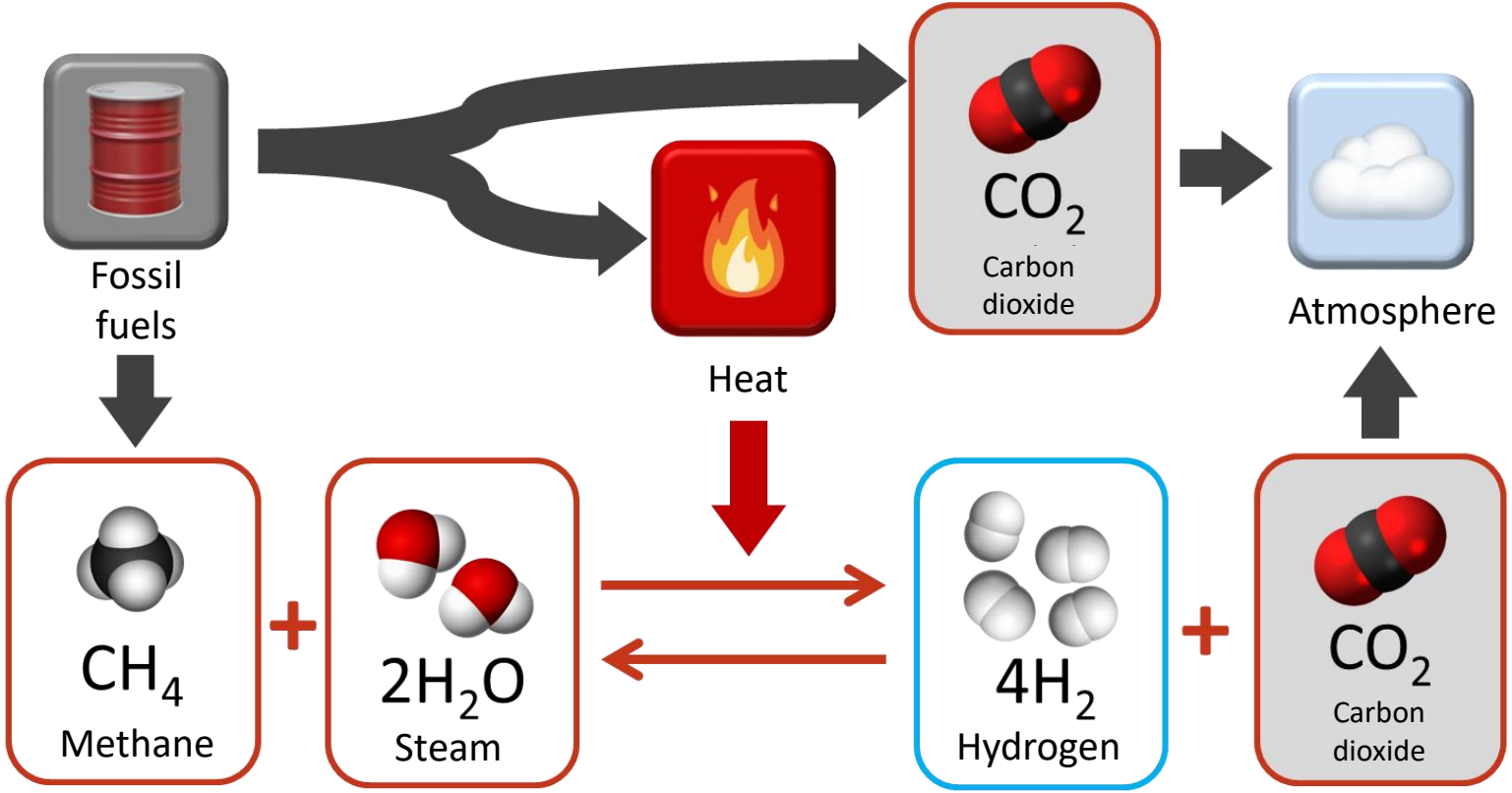
ENEA's CST technology

PCS facility, ENEA Casaccia Research Center Italy

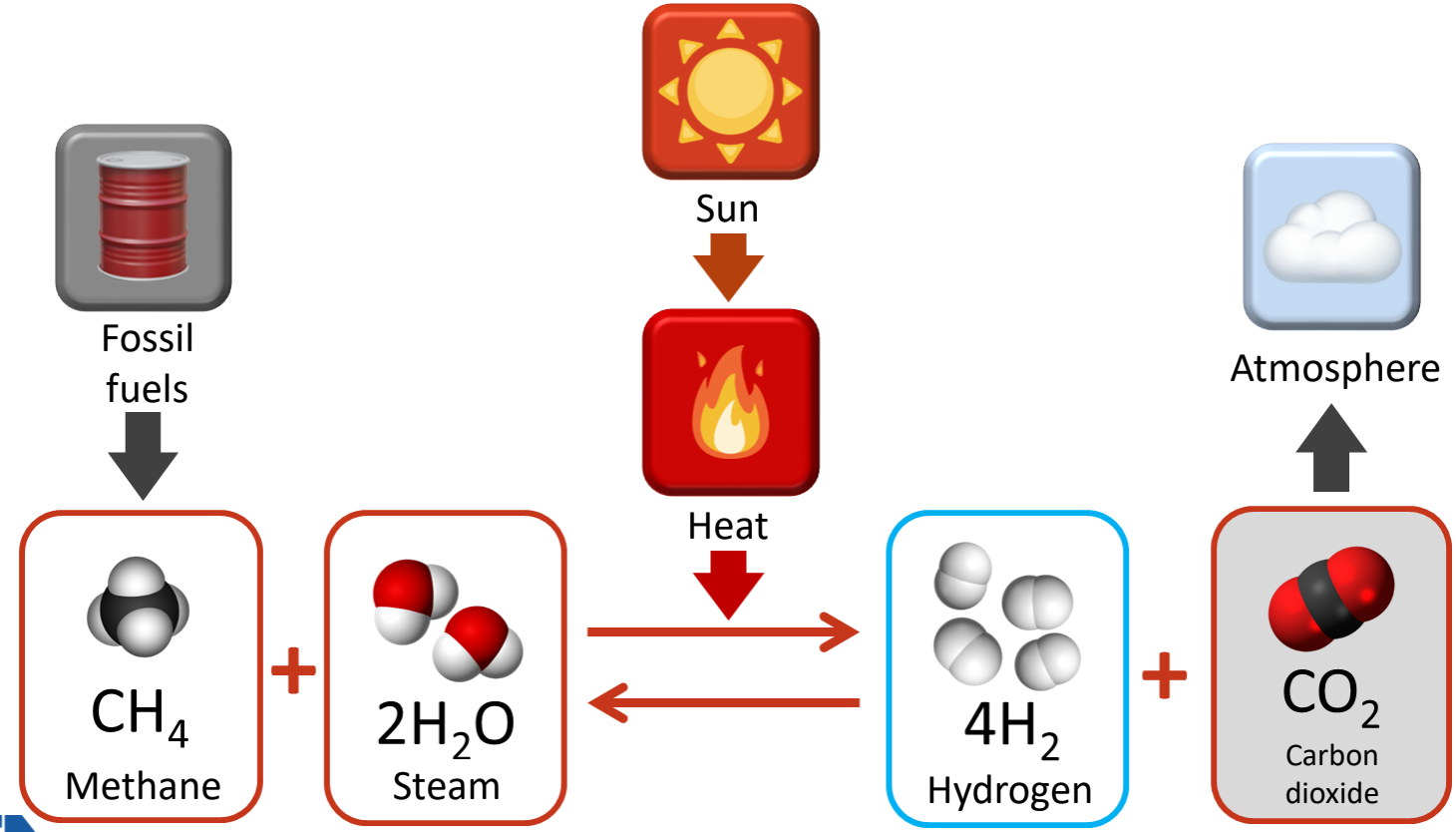
MATS plant, Borg El-Arab, Egypt



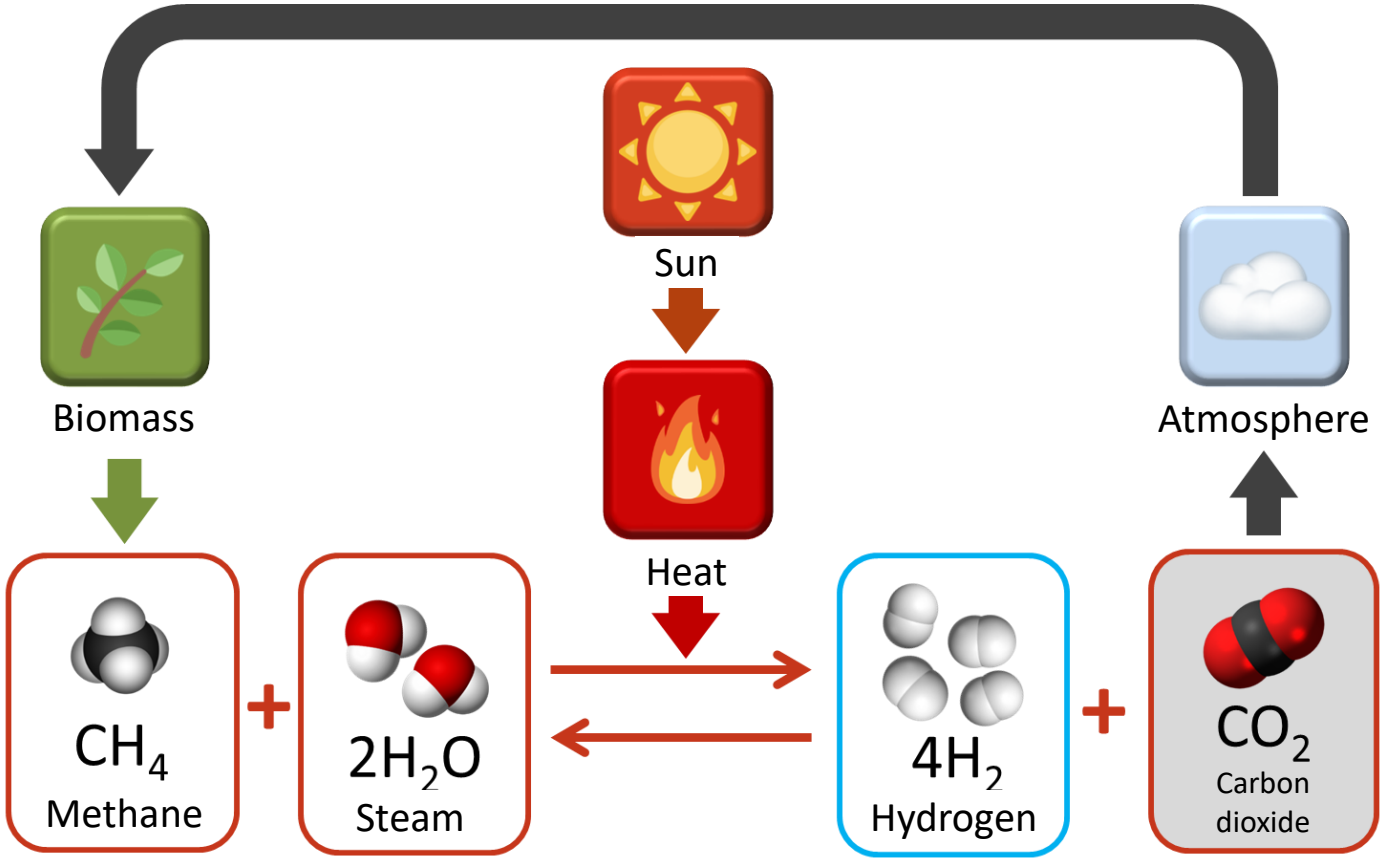
Conventional reforming



Solar reforming

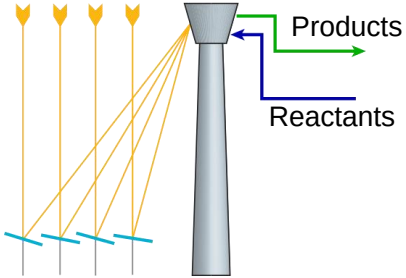


Solar reforming of biogas

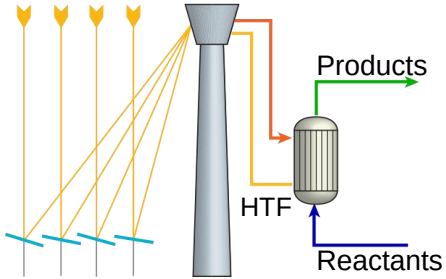


High temperature solar reforming

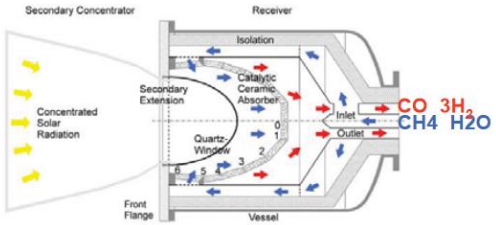
Directly irradiated process



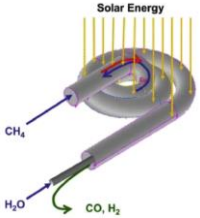
Use of heat transfer fluid



Examples of receiver-reactors concepts:



Tamme et al. J Sol Energy Eng 2001;123(2):160



Agrafiotis et al. Renew Sustain Energy Rev 2014;29(0):656

Main challenges:

- High temperatures
- Lack of consolidated thermal storage solutions
- Discontinuous operation
- Receiver-reactor design (directly irradiated process)

Low temperature solar reforming: CoMETHy project

Conventional SMR → **CoMETHy project**

T = 700 - 900 °C → T = 450 - 550 °C

Advantages:

- Lower-grade materials
- Higher safety
- Single reactor for SR and WGS
- **Use of solar power from CSP with MS**

→

- Up to 100% H_2 from renewables
  - Solar upgrading of fossil fuels
  - Reforming of renewable feedstocks
- Facilitated CO_2 capture

Drawbacks:

- Low hydrogen yield → Membrane reactor
- Slow reaction kinetics → Active and stable catalysts
- Low catalyst bed exploitation → Monolithic solid foam catalyst carriers

CoMETHy: plant concept

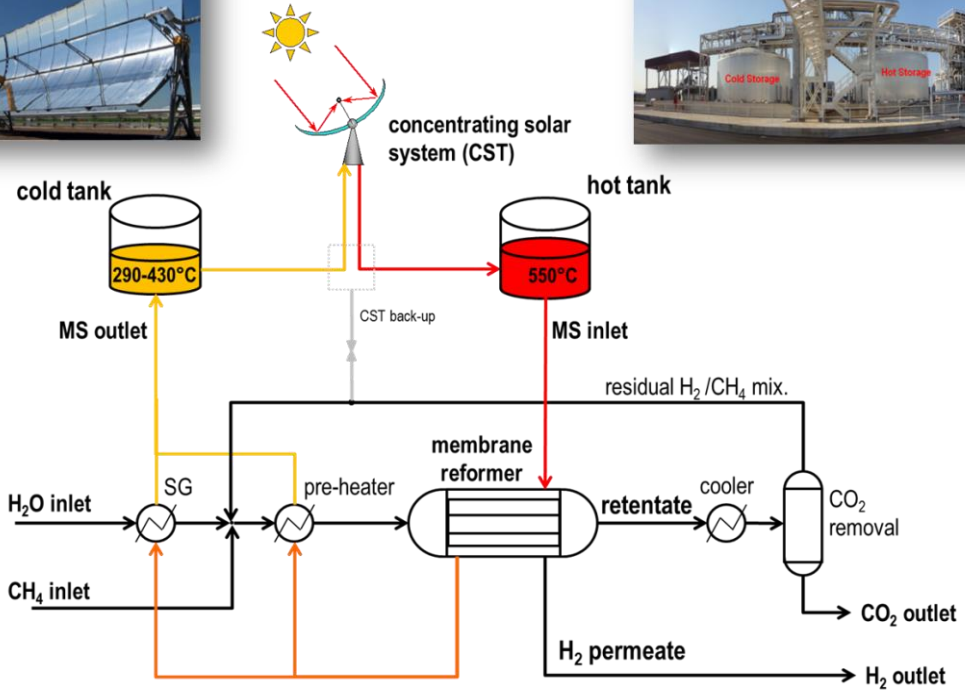
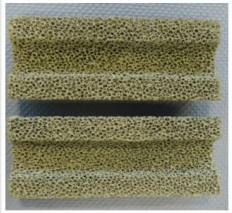
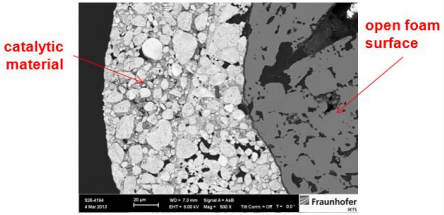


Image source: https://doi.org/10.1016/j.ijhydene.2020.09.070

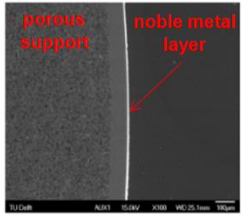
CoMETHy: development of components

Advanced catalysts for low-temperature steam reforming (NG, biogas, ethanol)

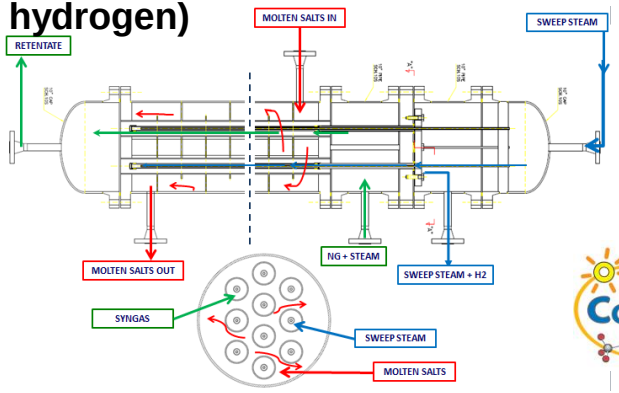




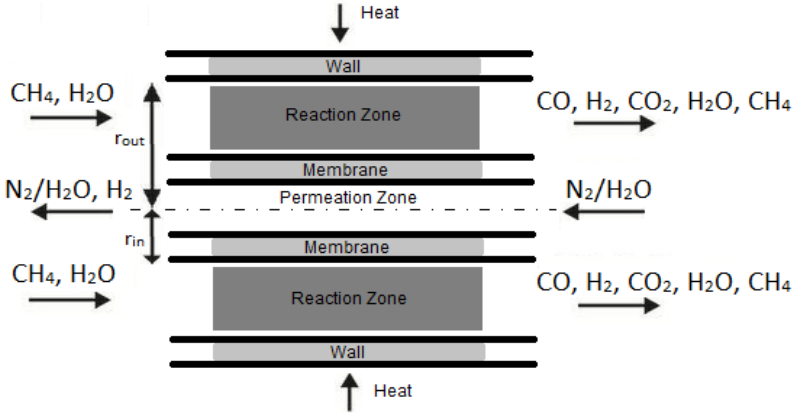
Selective membranes for hydrogen separation

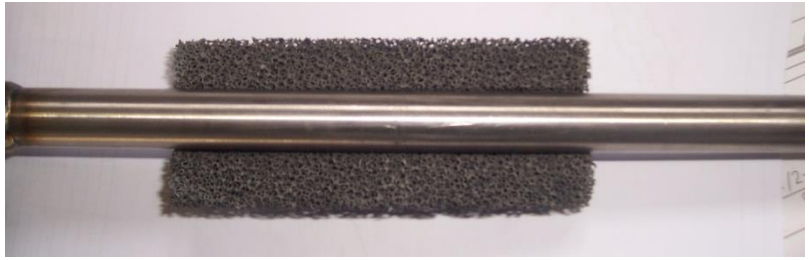


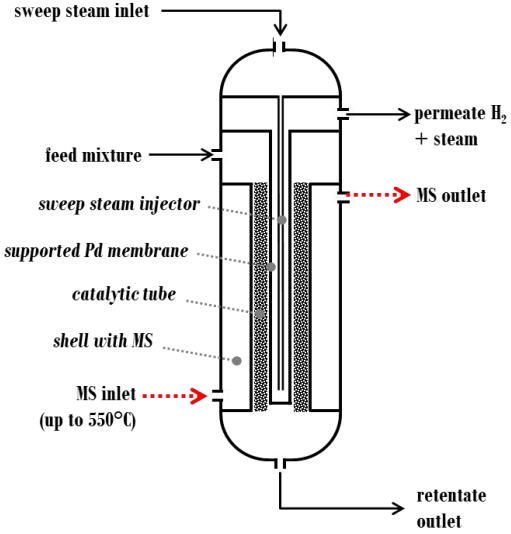
MS-heated membrane reformer (2Nm^3/h pure hydrogen)

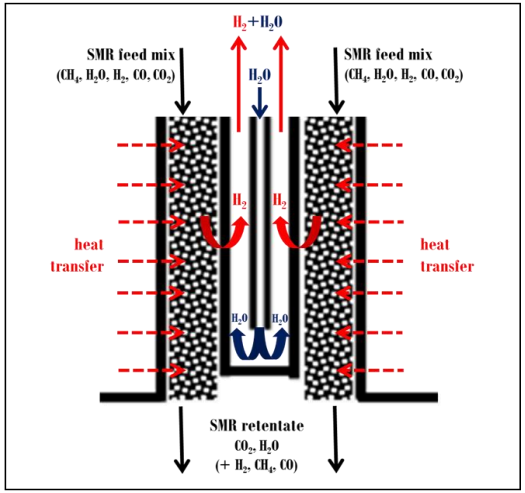


CoMETHy: membrane reactor

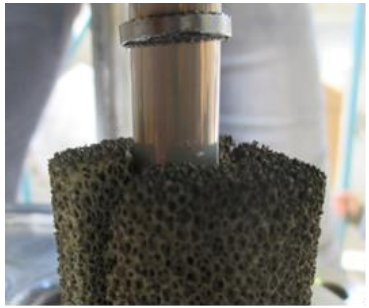








CoMETHy: membrane reactor



(a)

(b)

(c)

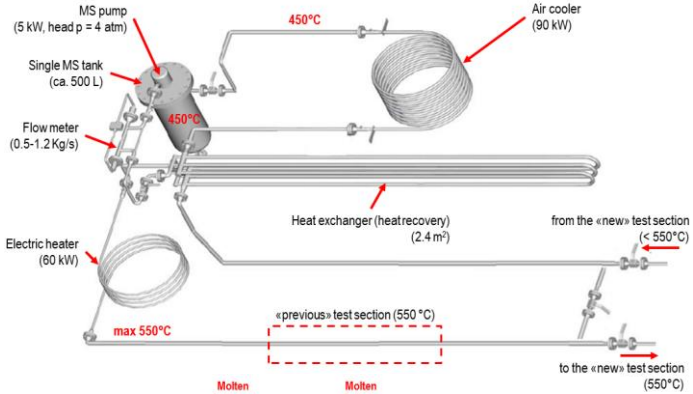
(d)

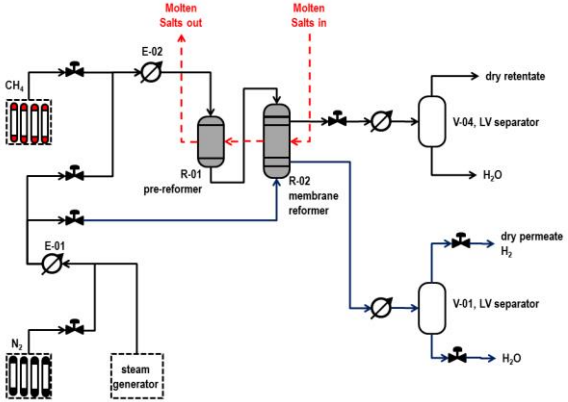
CoMETHy pilot plant

Membrane reactor

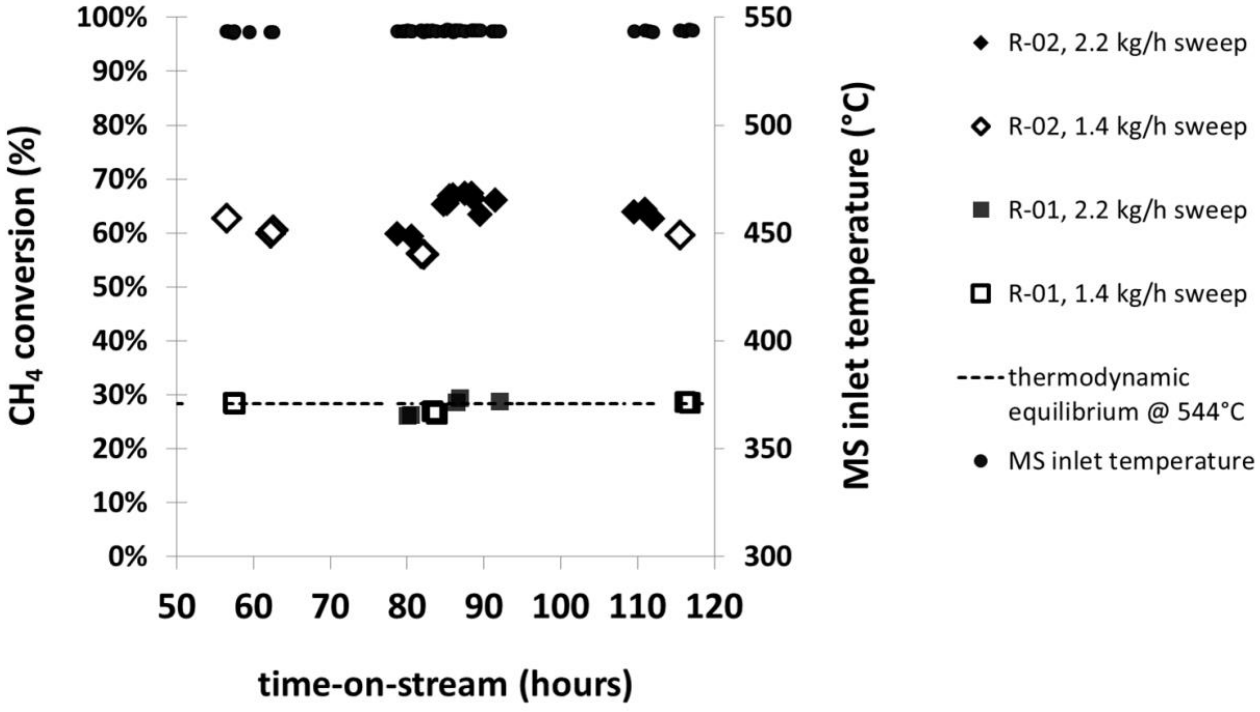
ENEA MoSE loop

Overview of chemical section





CoMETHy pilot plant testing results



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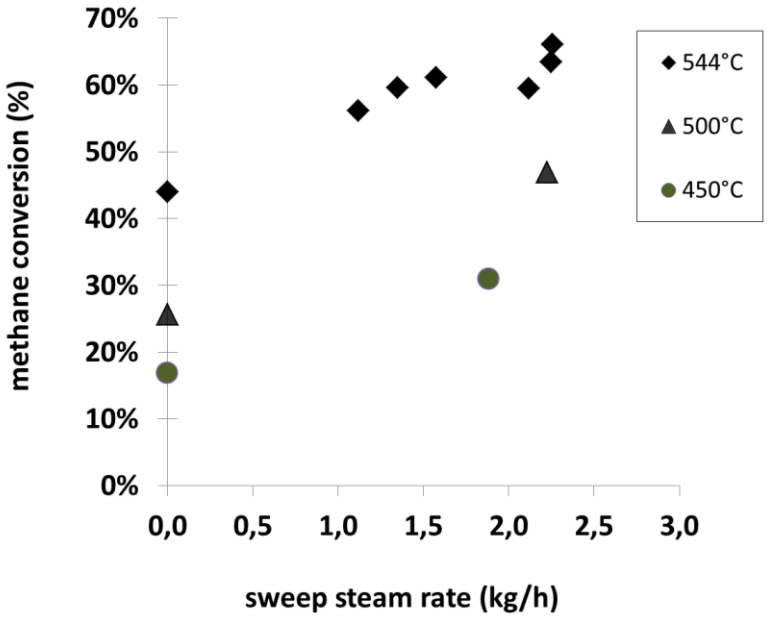
CoMETHy pilot plant testing results



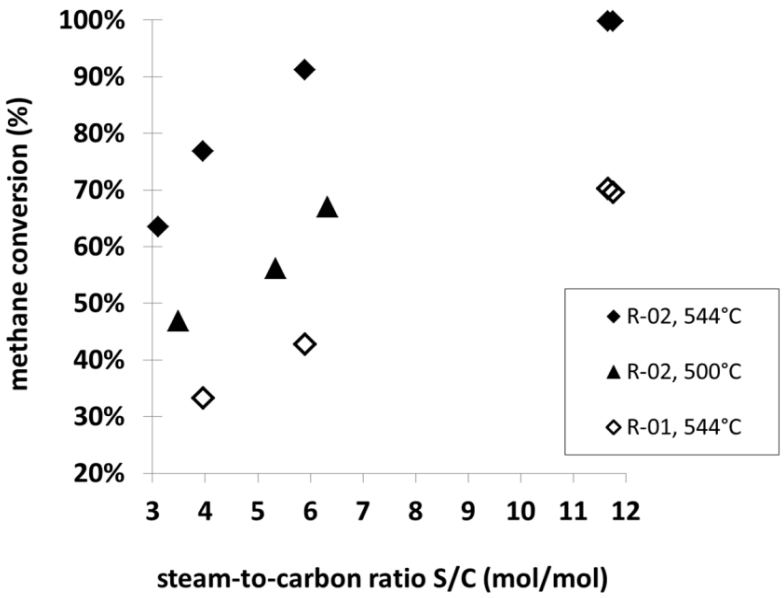
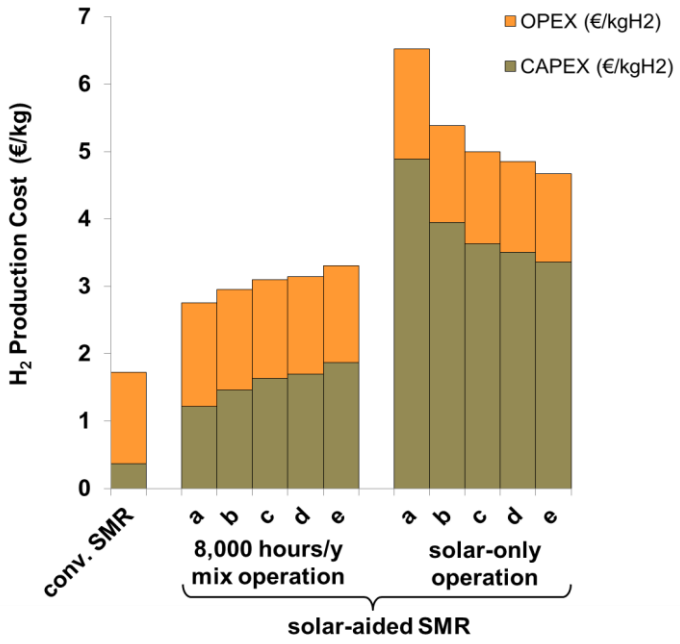
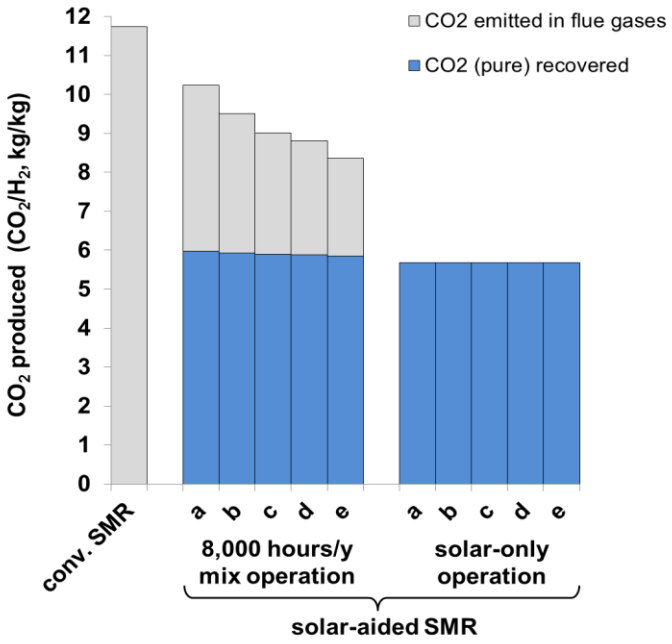


Image source: https://doi.org/10.1016/j.ijhydene.2020.09.070

Scaleup and techno-economic analysis

- Capacity:1,500 Nm^3/h

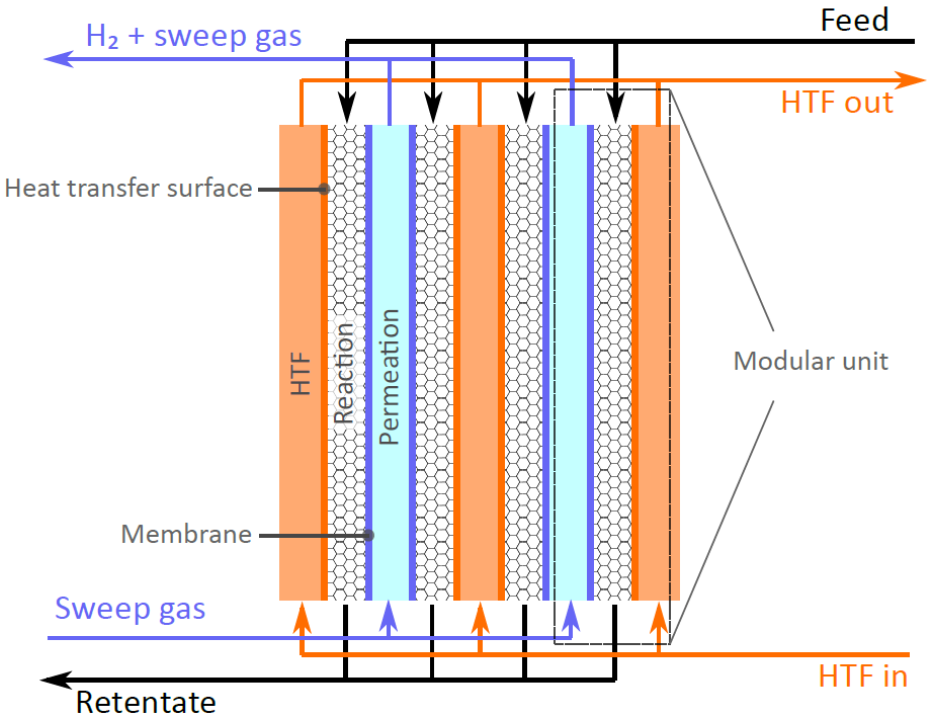


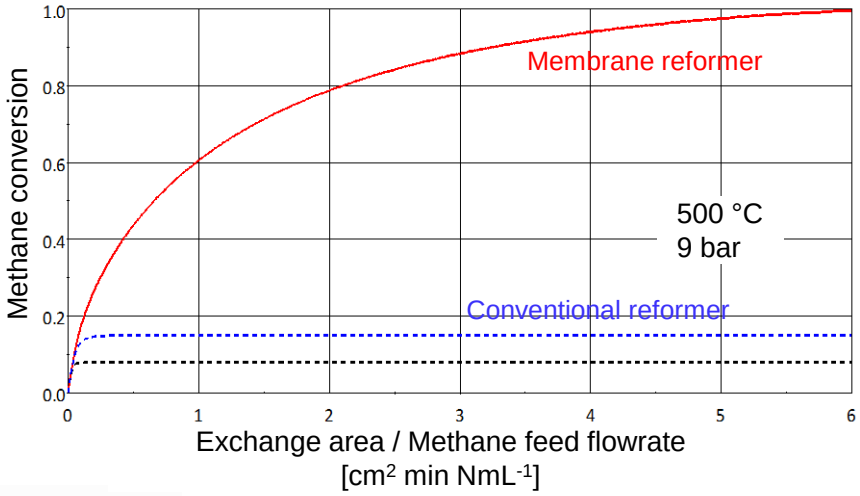


Hours/year of solar operation	
a	1987
b	2961
c	3608
d	3872
e	4456

Source: https://doi.org/10.1016/j.ijhydene.2021.08.096

Recent developments: planar reactor





This work was funded by the
Italian Ministry of Economic Development
though the «Electric System Research» programme
2019-2021 implementation plan

Conclusions

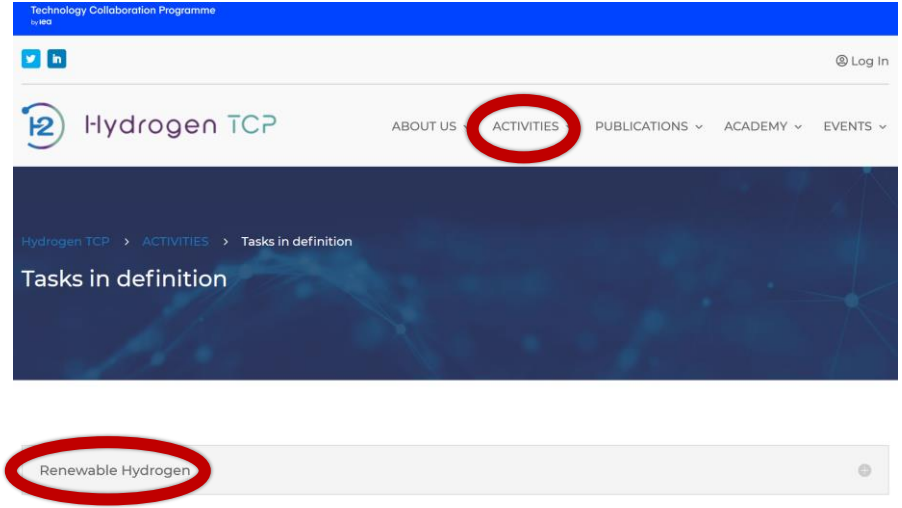
Solar reforming:

- is an alternative and potentially carbon-neutral hydrogen production route
- does not require radical technological changes in the current hydrogen production paradigm and could readily be taken up by the industry
- can support energy transition
- could complement electrolysis in meeting the growing hydrogen demand, also in a fully decarbonized system (if renewable feedstocks, e.g., biogas, are used)

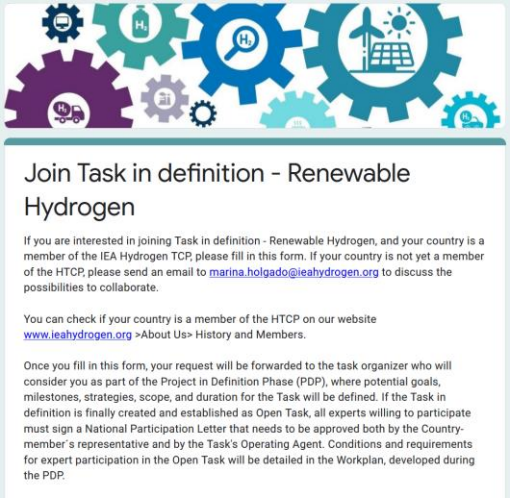
New task on renewable H2 production within IEAhydrogen TCP

If you want to know more about this initiative or join us in the definition phase, please fill in the form you can find the **Tasks in Definition** section of the Hydrogen TCP website

https://www.ieahydrogen.org/



New expert application form



Join Task in definition - Renewable Hydrogen

If you are interested in joining Task in definition - Renewable Hydrogen, and your country is a member of the IEA Hydrogen TCP, please fill in this form. If your country is not yet a member of the HTCP, please send an email to marina.holgado@ieahydrogen.org to discuss the possibilities to collaborate.

You can check if your country is a member of the HTCP on our website www.ieahydrogen.org >About Us> History and Members.

Once you fill in this form, your request will be forwarded to the task organizer who will consider you as part of the Project in Definition Phase (PDP), where potential goals, milestones, strategies, scope, and duration for the Task will be defined. If the Task in definition is finally created and established as Open Task, all experts willing to participate must sign a National Participation Letter that needs to be approved both by the Country-member´s representative and by the Task's Operating Agent. Conditions and requirements for expert participation in the Open Task will be detailed in the Workplan, developed during the PDP.

Thank you

for your attention!

Luca.turchetti@enea.it

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