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Centro Interuniversitario di Ricerca sull'Inquinamento e sull'Ambiente - mauro Felli

Centro Ricerca Biomasse
Biomass Research Centre

STUDIUM GENERALE CIVITATIS PERUSII
A.D. MCCCVIII

GBEP – UNECE - FAO
13° meeting of the Working Group on Capacity Buildings for Sustainable Energy (WGCB)

Green Bio-Hydrogen production from lignocellulosic biomass

prof. Franco Cotana
EU SET-Plan Co-Chair IWG8 - Renewable Fuels for Sustainable Transports and Bioenergy

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CIRIAF – Interuniversity Research Centre on Pollution and Environment M. Felli

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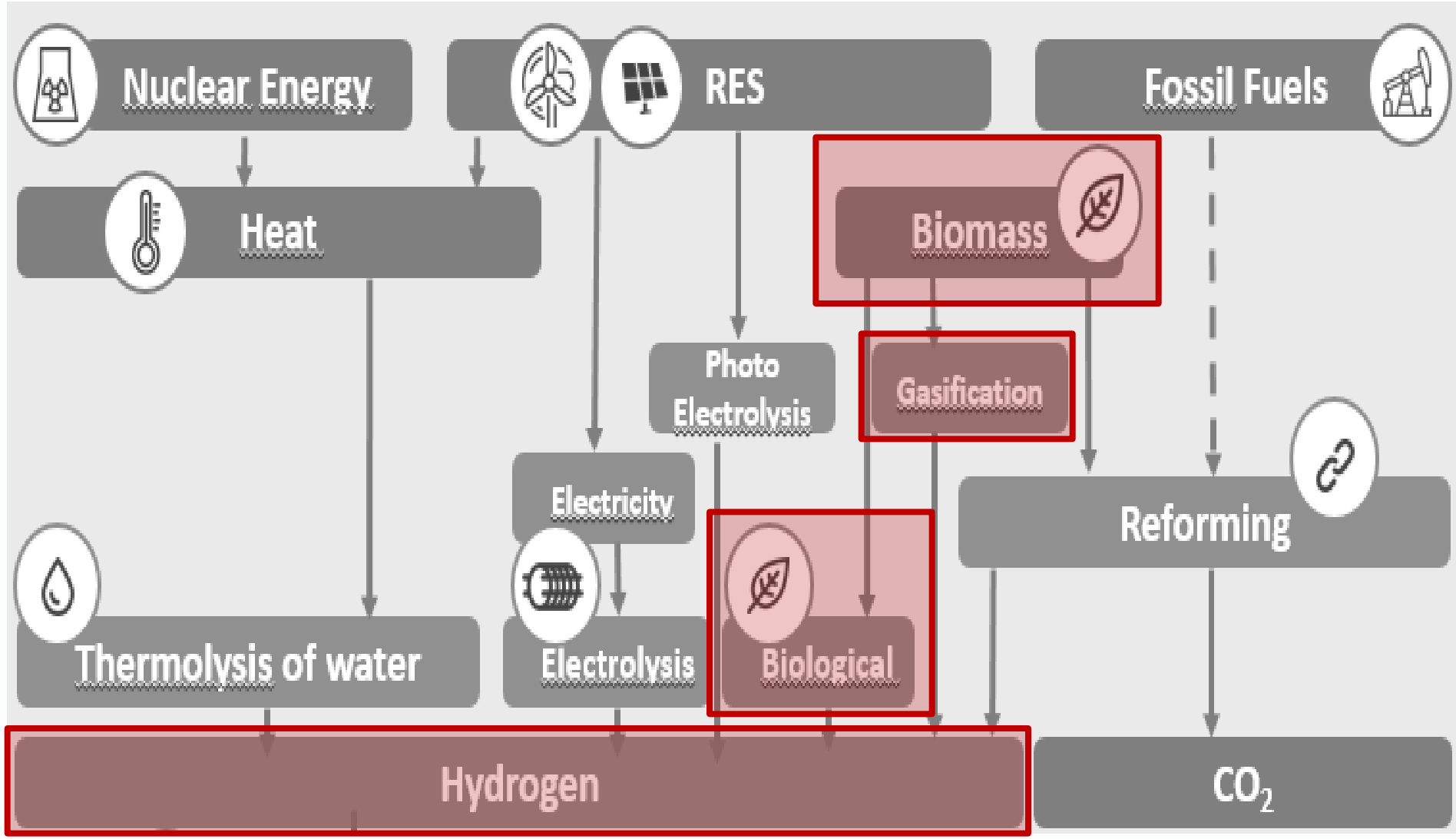
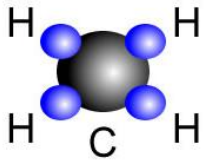
Department of Engineering

HYDROGEN PRODUCTION TECHNOLOGIES

1.Nuclear Energy; 2.RES Renewable Energy 3.Fossil Fuels (Coal or Methane)

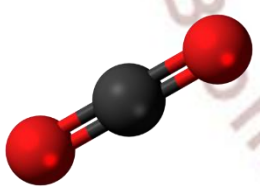


Bio-H2 from Steam reforming of bio-CH4



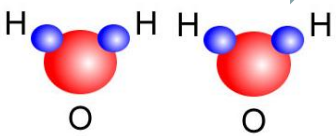
Bio-CH_4

CO_2

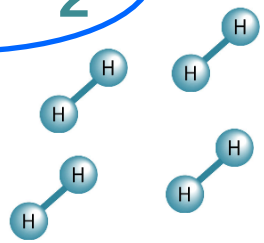


Bio-H_2

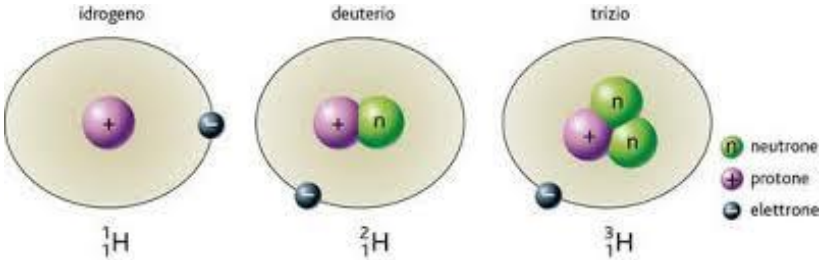
2 H_2O steam



Steam REFORMING from bio-Methane



$$2H_2O + CH_4 \rightarrow 4H_2 + CO_2$$



European forests are expanding. Over the last thirty years, the increase has been about **9%** and, according to the latest estimates, in 2020 they reached 227 million hectares, equal to over a third of the entire surface of the continent.

Table 1.1-3: Forest area and annual change in forest area, by region, 1990-2020 and 2010-2020

Region	1990	2000	2005	2010	2015	2020	Annual change 1990-2020	Annual change 2010-2020
	1 000 ha						%	
North Europe	69 943	70 823	70 767	70 926	71 202	71 299	+0.06	+0.05
Central-West Europe	35 020	36 382	37 178	37 864	38 447	38 966	+0.36	+0.29
Central-East Europe	41 731	42 773	43 280	43 841	44 471	44 735	+0.23	+0.20
South-West Europe	24 910	28 760	30 162	30 841	31 176	31 466	+0.78	+0.20
South-East Europe	36 459	37 339	38 210	39 442	40 196	40 887	+0.38	+0.36
EU-28	147 971	154 754	157 592	159 673	161 413	162 422	+0.31	+0.17
Europe	208 062	216 077	219 597	222 914	225 493	227 353	+0.30	+0.20

Note: Data coverage as % of total regional forest area: 100%; data cover all countries, for those not reporting on the year 2020 the last available information was used.

Credit: Forest Europe - rapporto 2020

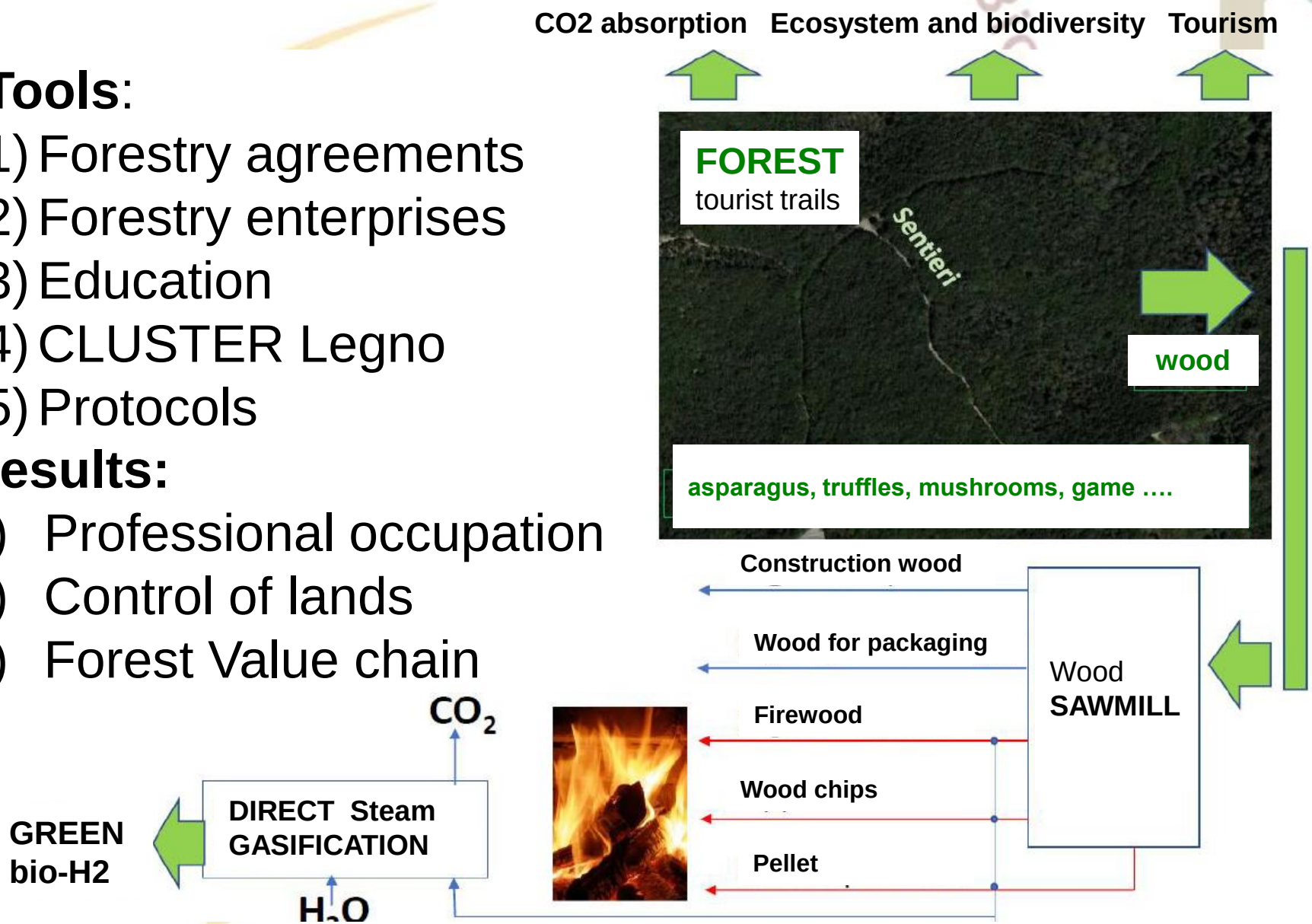
Multi-functionality **FOREST BIODISTRICT**

Tools:

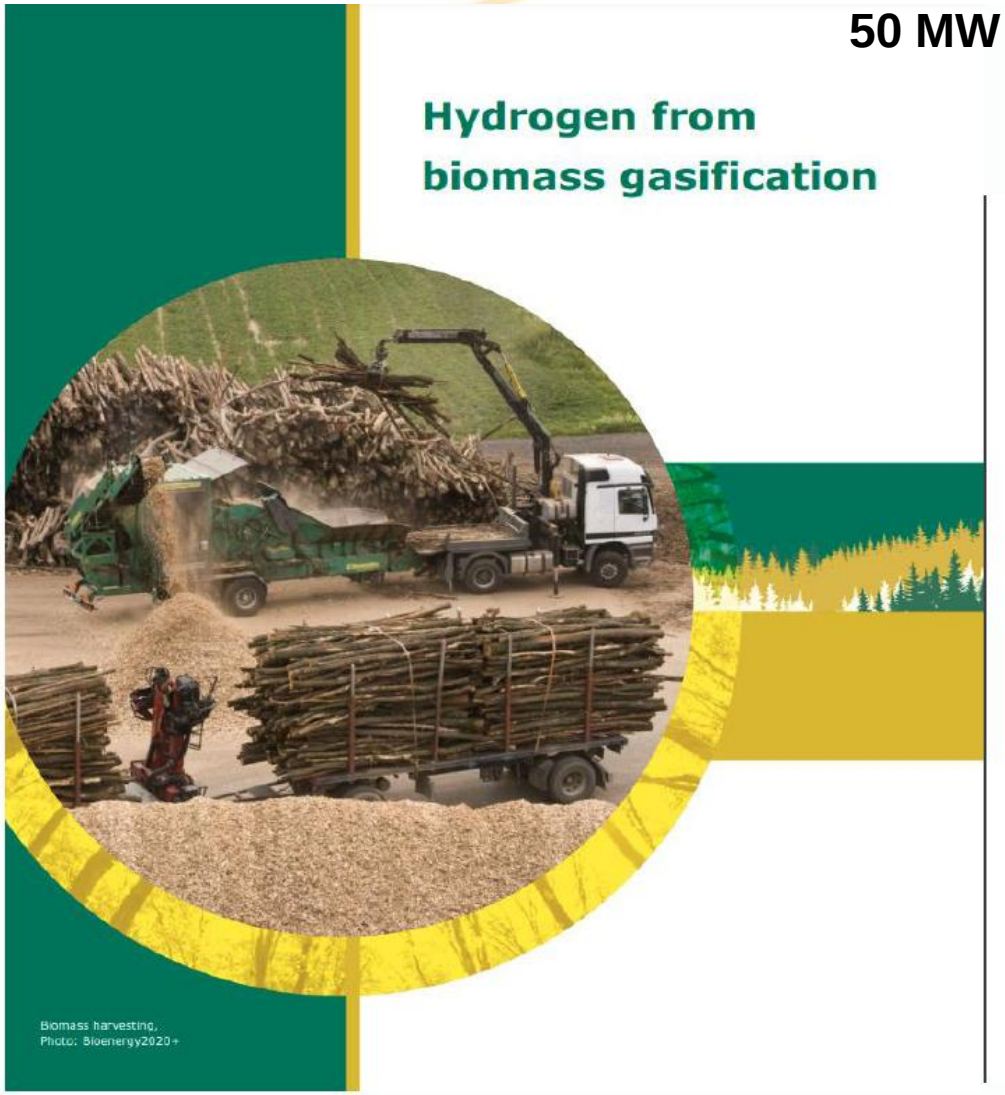
1) Forestry agreements
2) Forestry enterprises
3) Education
4) CLUSTER Legno
5) Protocols

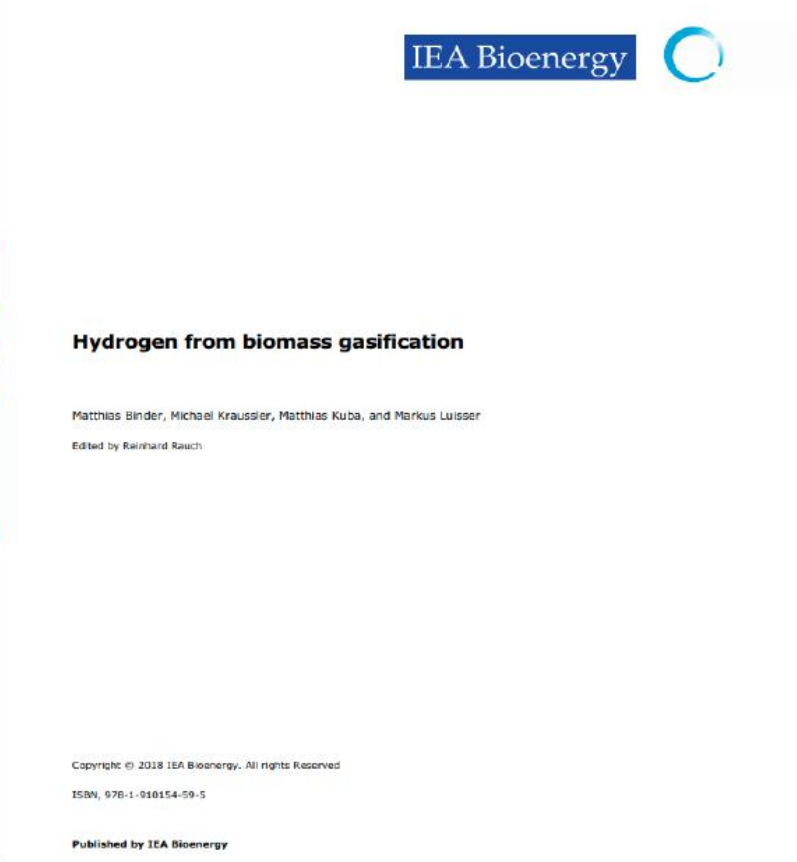
Results:

1) Professional occupation
2) Control of lands
3) Forest Value chain

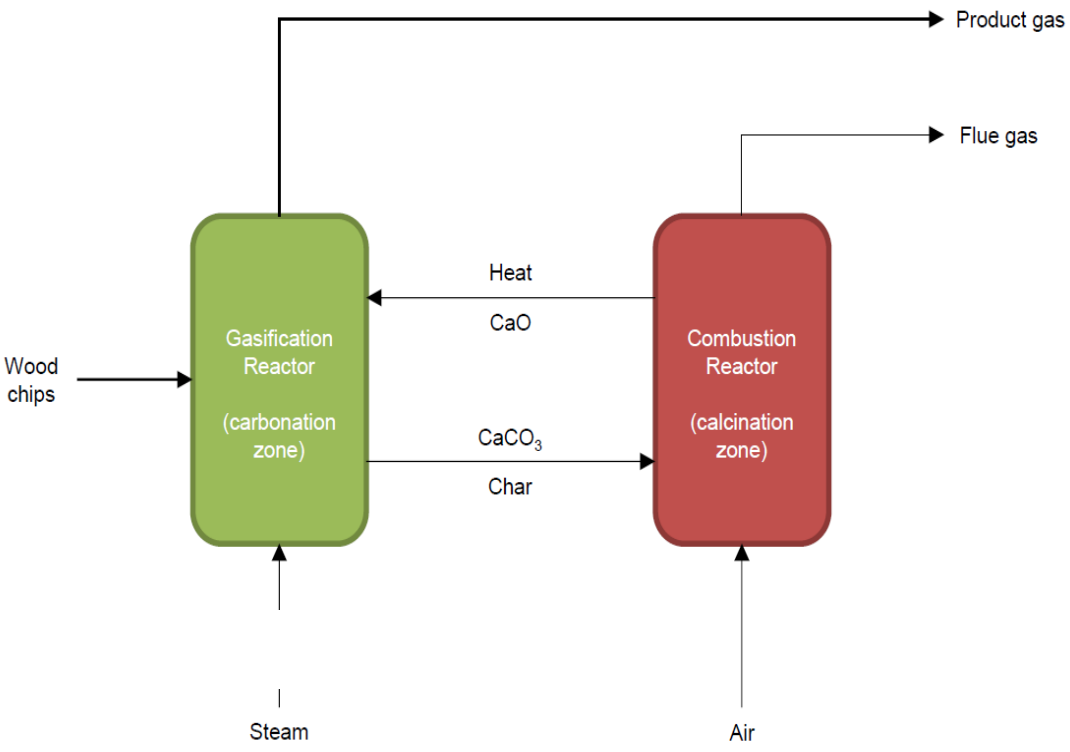


Green bio-hydrogen from lignocellulosic biomass at the selling price 2.7 €/kg, in the first commercial plant (TRL8 / 9) from: 50 MW output of bio-H2





Bio-Hydrogen (blù color) from wet wood

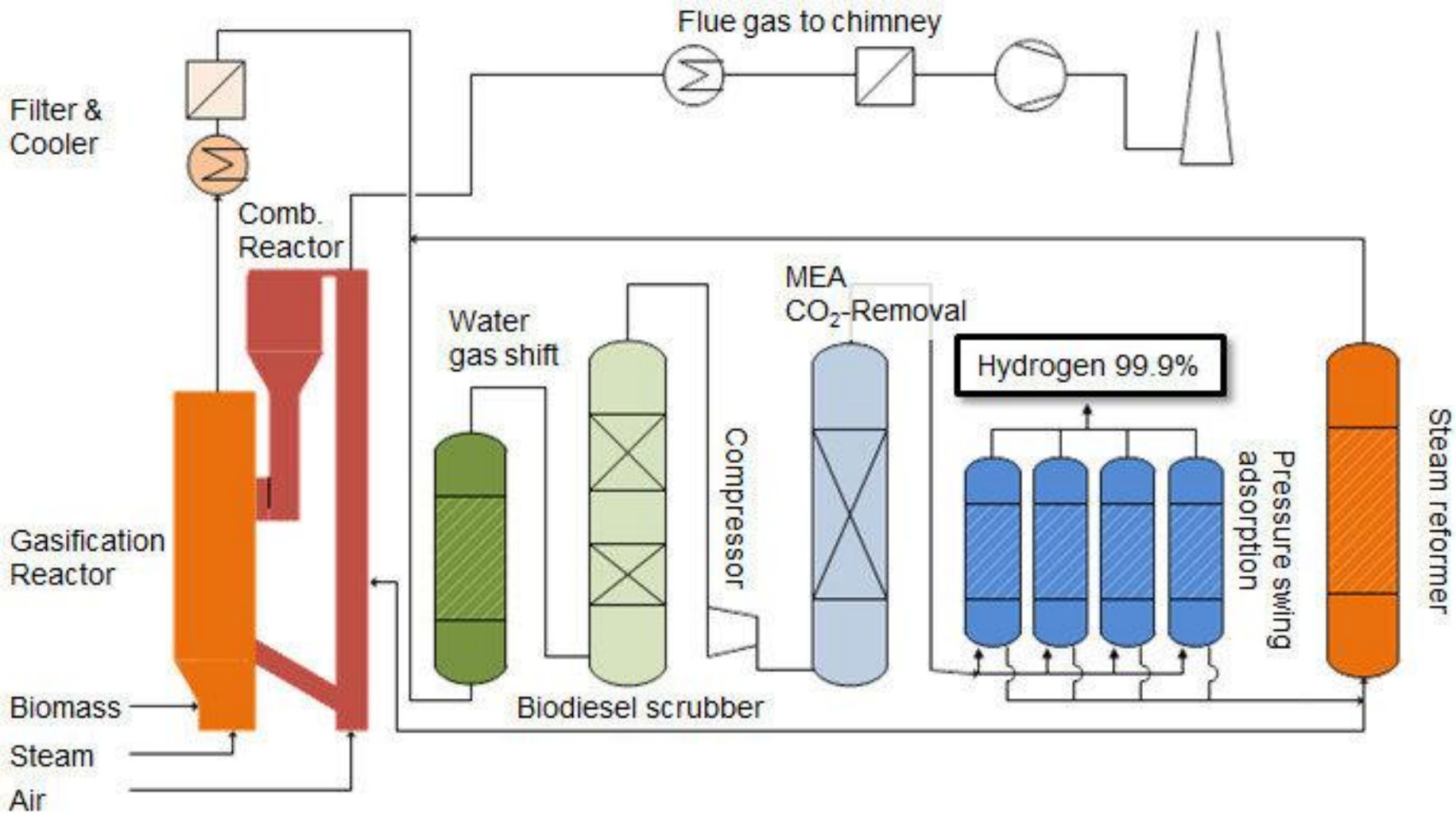


Principle of SER process based on biomass.

Typical product gas composition of the SER process.

Components	Values	Units
H_2	73%	$m^3 \cdot m^{-3}$
CO	8%	$m^3 \cdot m^{-3}$
CO_2	6%	$m^3 \cdot m^{-3}$
CH_4	11%	$m^3 \cdot m^{-3}$
C_xH_y	2%	$m^3 \cdot m^{-3}$
Tar (excl. BTEX)	~10	$g \cdot m^{-3}$

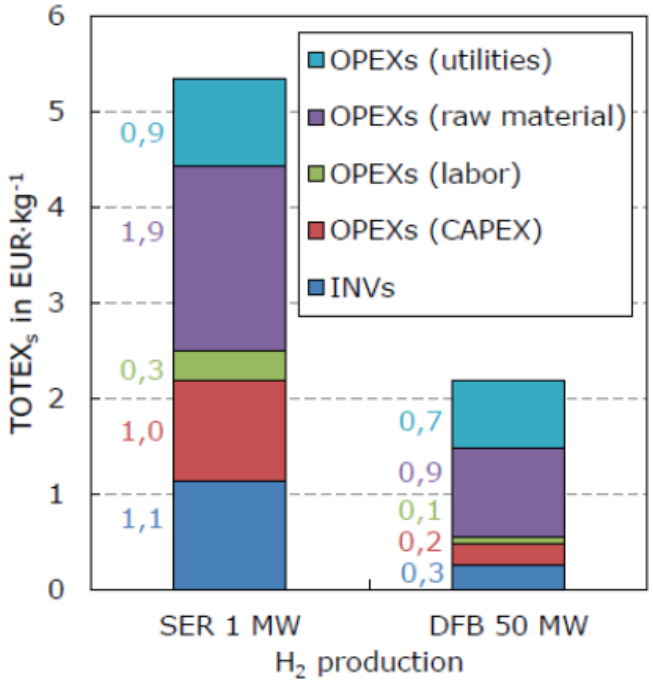
The plants of GUSSING in AUSTRIA and SENDEN in GERMANY



Selling Price of green bio-Hydrogen from wood cellulosic biomass

Comparison of the calculated hydrogen selling price, based on the assumption NPV = 0.

Hydrogen production capacity	SER 1 MW	DFB 50 MW
Hydrogen selling price in EUR·kg^{-1}	5.49	2.70



Comparison of the calculated TOTEXs based on the three different H2 production chains and on the three different H2 production capacities.

The green H2 is

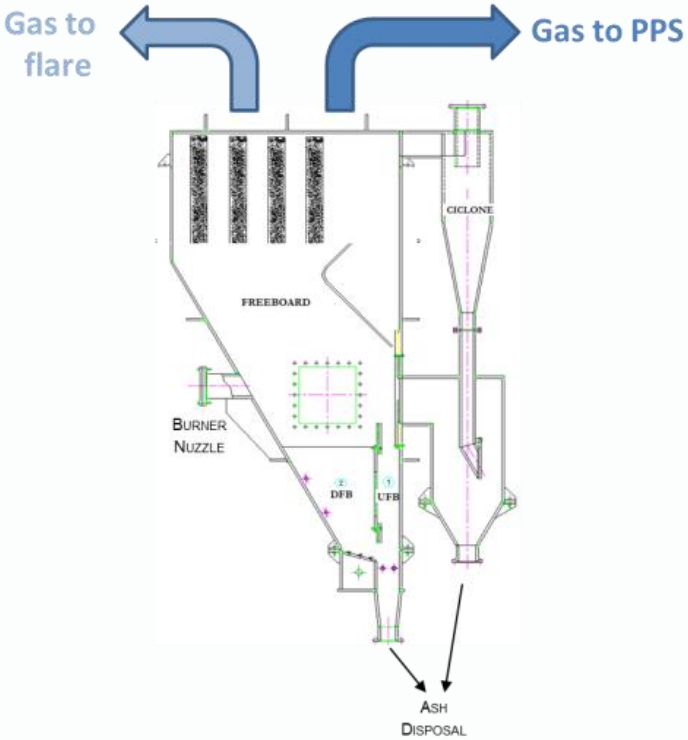
SENDEN in GERMANY wood Steam Gassification plant
50 MW OUTPUT Clean bio-Hydrogen

1kg bio-H2 each 12 kg of dray wood chip

Steam Gasification from Lignocellulosic Biomass

Hydrogen Production from Gasification ENEA

UNIfHY Project (IT)



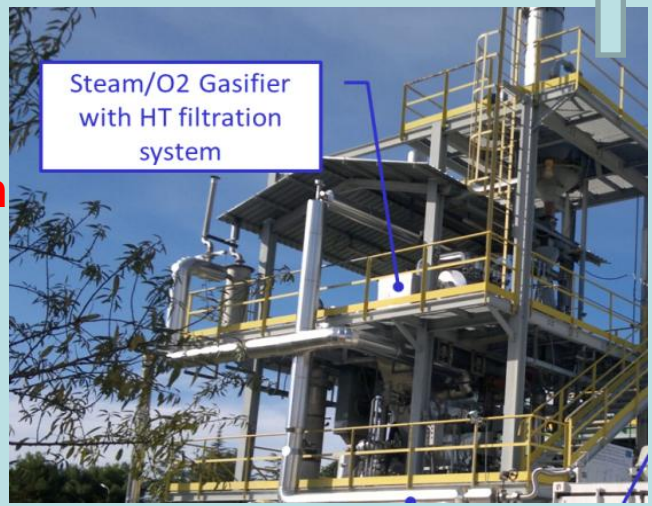
12 Kg of Wood Chip – Path 1 vs 2 to H2

20Kg air

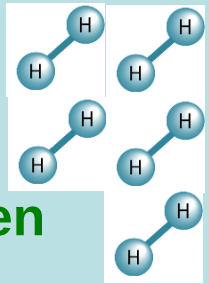
Steam Gasification

6Kg CO2 storage CCS/CCU

1. Direct conversion



1 Kg



Green Bio-Hydrogen

0,25 Kg

Bio-Char
fertilizer soil conditioner

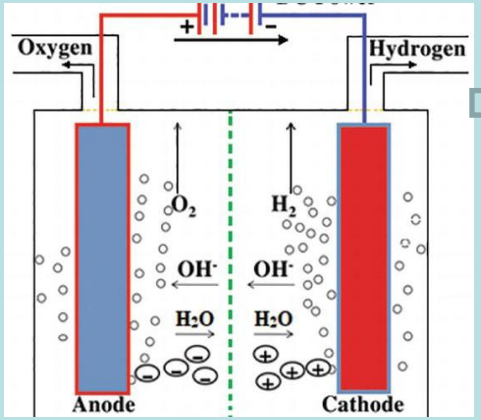
Dry Gasification

2. Biomass to Power

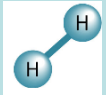
CO2

10 KWh

Power To H2



0,18 Kg Green Hydrogen



Co-Generator Gasifier

0,25 Kg
Bio-Char

Electrolyzer

Note **>80% Energy Lost in Path 2**

2050 : Italian economy decarbonization

Next 28 y

a) Energy efficiency +30%: reduction of energy consumption : from 125 Mtoe to **90 MToe**

b) Renewable energy production + 77% : +70 MToe (RE today **20,7** MToe)..

Il mix di energie rinnovabili sfruttabile annuo per la decarbonizzazione:

-Eolico	+ **10,0%** (pari a **9** Mtoe)
-Idroelettrico	+ **2,0%** (pari a **1,8** Mtoe)
-Fotovoltaico	+ **35,0%** (pari a **31,5** Mtoe_280 GWp 170.000 ha)
-Biomasse (incluso biogas)	+ **15,0%** (pari a **13,5** Mtoe)
-**Geotermia** a alta entalpia	+ **1,5%** (pari a **1,35** Mtoe)
-**Geotermia a bassa entalpia** per **Usi termici** –Riscaldamento , aria e acqua di falda con Pompe di Calore	+ **12,0%** (pari a **10,8** Mtoe)
-Rifiuti (9 Mton/y indiff=3Mton **CSS**)	+ **1,5%** (pari a **1,35** Mtoe)

from tot **FER the18% are green Hydrogen** (**16** Mtoe = 5,4 Mil ton H_2 # **60% Bio-H2**)

Tot. increase RE +77% **(70 MToe)**

RE today **+ 23%** **(20,7** MToe)..

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