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
HYDROGEN PRODUCTION TECHNOLOGIES

1. Nuclear Energy; 2. RES Renewable Energy; 3. Fossil Fuels (Coal or Methane)
Bio-H2 from Steam reforming of bio-CH4

$2\text{H}_2\text{O} + \text{CH}_4 \rightarrow 4\text{H}_2 + \text{CO}_2$

BIOGAS/Bio-Methane PLANT
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.

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

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

CO2 absorption  Ecosystem and biodiversity  Tourism

WOOD

SAWMILL

Construction wood

Wood for packaging

Firewood

Wood chips

Pellet

asparagus, truffles, mushrooms, game ...

DIRECT Steam GASIFICATION

H2O

GREEN bio-H2

FOREST tourist trails

asphalt, wood

Sawmill
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
Typical product gas composition of the SER process.

<table>
<thead>
<tr>
<th>Components</th>
<th>Values</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{H}_2 )</td>
<td>73%</td>
<td>( \text{m}^3\cdot\text{m}^{-3} )</td>
</tr>
<tr>
<td>( \text{CO} )</td>
<td>8%</td>
<td>( \text{m}^3\cdot\text{m}^{-3} )</td>
</tr>
<tr>
<td>( \text{CO}_2 )</td>
<td>6%</td>
<td>( \text{m}^3\cdot\text{m}^{-3} )</td>
</tr>
<tr>
<td>( \text{CH}_4 )</td>
<td>11%</td>
<td>( \text{m}^3\cdot\text{m}^{-3} )</td>
</tr>
<tr>
<td>( \text{C}_x\text{H}_y )</td>
<td>2%</td>
<td>( \text{m}^3\cdot\text{m}^{-3} )</td>
</tr>
<tr>
<td>Tar (excl. BTEX)</td>
<td>~10</td>
<td>g\cdot\text{m}^{-3}</td>
</tr>
</tbody>
</table>

Principle of SER process based on biomass.
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.

<table>
<thead>
<tr>
<th>Hydrogen production capacity</th>
<th>SER 1 MW</th>
<th>DFB 50 MW</th>
</tr>
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<tbody>
<tr>
<td>Hydrogen selling price in EUR·kg⁻¹</td>
<td>5.49</td>
<td>2.70</td>
</tr>
</tbody>
</table>

The green H2 is
SENDEN in GERMANY wood Steam Gassification plant
50 MW OUTPUT Clean bio-Hydrogen

1kg bio-H2 each 12 kg of dry wood chip
Hydrogen Production from Gasification

UNIfHY Project (IT)

Steam/O2 Gasifier with HT filtration system

Portable Purification System for H2 prod.

Gas line to the PPS

Gas to flare

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

1. Direct conversion

2. Biomass to Power

Steam Gasification

Steam/O2 Gasifier with HT filtration system

Co-Generator Gasifier

10 KWh Power To H2

6Kg CO2 storage CCS/CCU

0,25 Kg Bio-Char

Green Bio-Hydrogen

0,18 Kg Green Hydrogen

Note >80% Energy Lost in Path 2

12 Kg Wood chip

20Kg air

1 Kg

Green Hydrogen

0,25 Kg Bio-Char fertilizer soil conditioner

12 Kg of Wood Chip – Path 1 vs 2 to H2
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 the 18% are green Hydrogen (16 Mtoe = 5.4 Mil ton H₂ # 60% Bio-H2)

Tot. increase RE +77% (70 MToe)

RE today + 23% (20.7 MToe)
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