ECONOMIC AND ECOLOGIC ANALYSIS OF BIOMASS-BASED ENERGY CARRIERS IN AUSTRIA – CONTRIBUTION TO DECARBONIZINGTHE ENERGY SECTOR BY 2040

Nadine GUERER[1],Amela AJANOVIC[2], Reinhard HAAS[3]

Core objective

The core objective of this paper is to determine and compare the economic and environmental performance of the following eight biomass-to-energy carrier chains:

(a) Forest residue pellets, wheat straw pellets → Fischer Tropsch (FT) - Diesel
(b) Wood chips → local heat, electricity, SNG
(c) Sawing by-products (Wood Industry by-products) → heat from heat boilers, electricity, SNG

In a next step, scenarios for the years 2030 and 2050 will be constructed for the eight biomass-based energy carriers mentioned above, in order to provide an outlook for their potential economic and environmental performances, in comparison to their conventional alternatives.

Method of approach

For the economic analysis of the biomass-to-energy carrier chains that are being analysed in this paper, energy and capital costs, as well as the following, other costs are being considered: transport, operation & maintenance, electricity, heat and labour costs. In a final step, the total production cost of a certain biomass-based energy carrier is then compared to its conventional alternative. The sum of the above mentioned variables represent the yearly total production costs, C_{total}, of a selected energy carrier – in this case, FT- Diesel, local heat, electricity, SNG and heat from heat boilers – from a selectged biomass fraction (feedstock, FS). This is summarized and expressed mathematically via **Equation 1**:

$$C_{total} = \frac{P_{FS}}{n_{ref}} + \frac{IC.\alpha}{T} + \frac{C_{O\&M}}{T} + R_{SP} \qquad [€/kWh] \qquad (1)$$

where:

EC……Energy content [kWh/ton FS]; FS…. Biomass fraction; P_{FS}…… FS costs [€/ton FS];
IC…… Investment costs [€/kW]; *n*…….. Refinery's efficiency; $C_{O\&M}$…..∑Op & Maintenance, transport, electricity, heat , labour costs [€/kW]; R_{SP}…. Revenue of by-products; T…. Full load hours [h/y]

For the environmental analysis of the selected biomass-energy carrier chains, the CO_2 input and the conversion efficiency for the feedstock in question, as well as the CO_2 input for the final energy carrier are considered. Subsequently, the biomass-based energy carrier's CO_2 balance is compared to the one of its conventional alternative, e.g. natural gas. The sum of the mentioned variables represents the CO_2 balance, CO_{2_SP}, for the production of a specific energy carrier – in this case FT-Diesel, local heat, electricity, SNG and the heat from heat boilers – from a specific biomass fraction (feedstock, FS). This is summarized and mathematically expressed in **Equation 2**:

$$CO_{2\_SP} = n_{FS} \,.\, CO_{2\_FS\_IN} + CO_{2\_BF\_IN} \qquad [kg\ CO_2/kg\ BF] \quad (2)$$

The CO_2 emissions ensuing due to growing a certain feedstock ($CO_{2\ FS\_IN}$) as well as the CO_2 emissions ensuing due to the production of a certain energy carrier ($CO_{2\ BF\_IN}$) can be further expressed in more detailed via **Equations 2.1. and 2.2.**:

$$CO_{2\,FS\_IN} = CO_2\,[Passive/Sink + Fertilizer + Fuel\,(FS) + Fuel\,(Transport)] \quad [kg\ CO_2/\ kg\ FS]\ (2.1)$$

$$CO_{2\,BF\_IN} = CO_2\,[Credits\,(By - Products) + Pressing^2 + BF\ Conversion + other\ WTT + Transport\,(Gas\ Station, TTW)] \quad [kg\ CO_2/\ kg\ BF]\ (2.2)$$

where[3]:

[1],[2],[3],[4] Energy Economics Group (EEG), Vienna University of Technology, Gußhausstraße 25 - 29, 1040 Vienna, +43 1 58801 - 370341, guerer@eeg.tuwien.ac.at, https://eeg.tuwien.ac.at

[2] Note that this step does not apply to every Biomass-Energy carrier chain

[3] Abkürzungen: WTT… well-to-tank, TTW…tank-to-wheel

η_{FS}… Efficiency of Biomass gasification process

$CO_{2\_FS\_IN}$ (CO_2 emissions ensuing due to growing a certain feedstock: $\sum CO_2$ (passive/sink, fertilizer, $fuel_{feedstock}$, $fuel_{transport}$) [kg CO_2/ kg FS]

$CO_{2\_BF\_IN}$ (CO_2 Emissions ensuing due to the production of a certain energy carrier) ….$\sum CO_2$ ($Credits_{by\text{-}products}$, Pressing, BF conversion, other WTT, $Transport_{gas\ station,}$TTW) [kg CO_2/kg BF]

***Figure 1** represents the segmented total production cost for pine forest residue pellets-to-FT diesel and wheat straw pellets-to-FT diesel chains, including CO_2 taxes in comparison to the corresponding Diesel price (EUR/kWh), all for the EU and year 2020. **Figure 2** represents CO_2 balances for the same chains for 2020, 2030 and 2050 compared to corresponding Diesel CO_2 (TTW emissions) for the EU.*
The long version of the paper will include a more detailed and comprehensive analysis of different biomass fractions and energy carriers (as mentioned in core objective section).

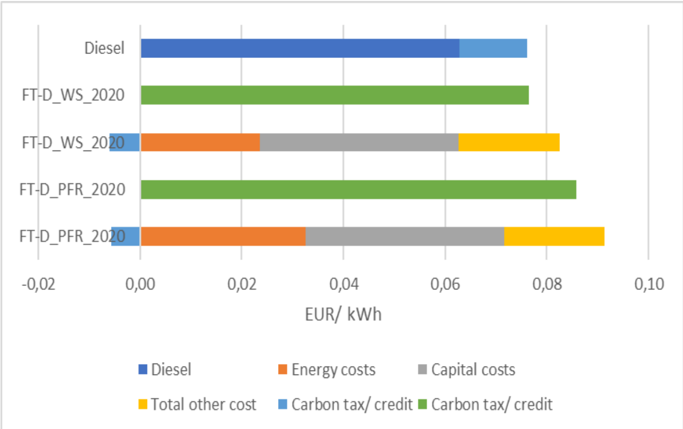

Fig. 1. Total production costs for wheat straw-to-FT diesel & forest residues-to-FT diesel chains incl. CO_2 taxes for 2020 compared to corresponding Diesel price (€/kWh)

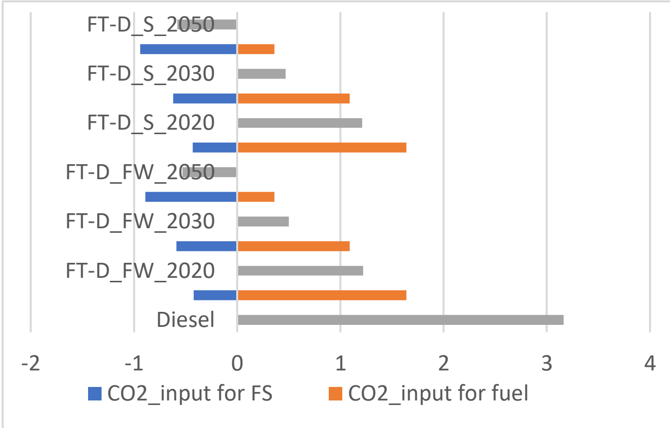

Fig. 2. CO_2 balances for forest wood-to-FT diesel & straw-to-FT diesel chains for 2020, 2030 and 2050 compared to corresponding Diesel CO_2 (TTW emissions) for the EU

Results[4]

The most important results are: (i) Fig. 1 describes the structure of the current total production cost of forest wood-to-FT diesel and straw-to-FT diesel chains and compares these with the corresponding total production cost of diesel for 2020 (€/kWh). Note, that for each biomass-to-fuel chain, next to the segmented production costs, the total production costs including CO_2 taxes are given. While we can see the advantages of CO_2 tax in its contribution to a decrease of the total costs / kWh of fuel for both FT diesel chains, in 2020 it is evidently more economically feasible to produce conventional diesel, including CO_2 taxes; ii) figure 2 depicts the CO_2 balances of forest wood-to-FT diesel and straw-to-FT diesel chains for the years 2020, 2030 and 2050 and compares these to the corresponding conventional diesel CO_2 balance. While it is evident that at present the ecologic performance of FT diesel is already superior to that of conventional diesel, the environmental benefits in terms of negative lifecycle carbon emissions (kg CO_2/kg fuel) are expected to continuously increase until 2050 for both biomass-to- FT diesel chains under study.

[4] Note that the results and conclusion sections are based on the environmental and economic analysis of FT-Diesel chains only.