Ecologic and economic assessment of biomass based energy carriers - a dynamic model for the optimization of biomass for energetic use

Case study: the economic and environmental assessment of selected Biomass-to-Fischer Tropsch (FT) diesel chains in the EU

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Introduction & Motivation I

- European Green Deal:
  - Reducing GHG emissions by at least 55% by 2030 and 90% by 2050 compared to 1990 levels (EU Commission 2019)
  - Rendering Europe the world's first climate-neutral continent by 2050 (EEA 2021)

→ Transition towards a sustainable energy & transport system + increase of market share of biofuels in EU transport sector necessary to reach Green Deal mandates

- EU Sustainable and Smart Mobility Strategy (Mobility and Transport 2022)

- Recast of the EU Renewable Energy Directive (RED II) (EU Parliament & Council 2018)

Introduction & Motivation II

- *Promotion of biofuels* in transport sector through carbon tax (€/ton CO_2) as regulating instrument

- *Decarbonization of transport sector* through carbon neutral technologies, e.g. electric vehicles powered with renewable energy or **bio-based fuels**

  - Previously: GHG emission reduction through blending mandates, e.g. bioethanol with gasoline (E10)
  - Superior environmental sustainability of 2nd generation biofuels (BF-2)

Selected biomass-to-FT diesel chains have a high potential as alternative fuel due to

a) increased ecological performance (lower life-cycle carbon emissions, no associated land-use- changes)

b) financial competitiveness (economies of scale)

Objective

(1) To determine and compare the present[1] **economic** and **environmental** performance of the following four Biomass-to-Liquid (BtL) fuel chains and conventional diesel:

(a) Forestry wood-to- FT diesel

→ Data based on previous study by Ajanovic et al. 2012 “The long-term prospects of biofuels in the EU-15 countries”

(b) Straw-to- FT diesel

→ Data based on previous study by Ajanovic et al. 2012 “The long-term prospects of biofuels in the EU-15 countries”

(c) Pine forest residue-to- FT diesel

→ Recent data based on EU Horizon 2020 Chemical Looping Gasification for Sustainable Production of Biofuels (CLARA[2]) project

(d) Wheat straw-to- FT diesel

→ Recent data based on EU Horizon 2020 CLARA[2] project

Conventional diesel

(2) To provide an outlook for the expected economic and environmental performances of the above mentioned BtL fuel chains and conventional diesel for 2030 and 2050

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[1] for the year 2020

[2] This work has received funding of the European Union’s Horizon 2020-Research and Innovation Framework Programme under grant agreement No. 817841 (Chemical Looping gasification foR sustainAble production of biofuels-CLARA).

Method of Approach

Economic analysis:

$$C_{total} = \frac{P_{FS}}{n_{ref}} + \frac{IC\,.\,\alpha}{T} + \frac{C_{O\&M}}{T} + R_{SP}$$

where:

EC……Energy content [kWh/ton FS]
FS…. Feedstock
P_{FS}……price FS [€/ton FS]
IC……investment costs [€/kW]
n……..efficiency of refinery
$C_{O\&M}$…..∑operation & maintenance, transport, labor, electricity, heat etc. [€/Kw]
R_{SP}…. Revenues side-products
T…. full load hours [h/yr]

Environmental analysis:

$$CO_{2\_SP} = n_{FS}\,.\,CO_{2\,input\,feedstock} + CO_{2\,input\,biofuel}$$

where:

η_{FS}……Feedstock conversion efficiency
$CO_{2\ input\ feedstock}$……∑CO_2 (passive/sink, fertilizer, $\text{fuel}_{feedstock}$, $\text{fuel}_{transport}$) [kg CO_2/ kg FS]
$CO_{2\ input\ biofuel}$….∑CO_2 ($\text{credit}_{by\text{-}products}$, pressing, BF conv., other WTT, $\text{transp.}_{fill.\ stat.,}$TTW) [kg CO_2/kg BF]

Abbreviations: WTT… well-to-tank, TTW…tank-to-wheel

Economic Assessment, BtL fuel chains (a) & (b)

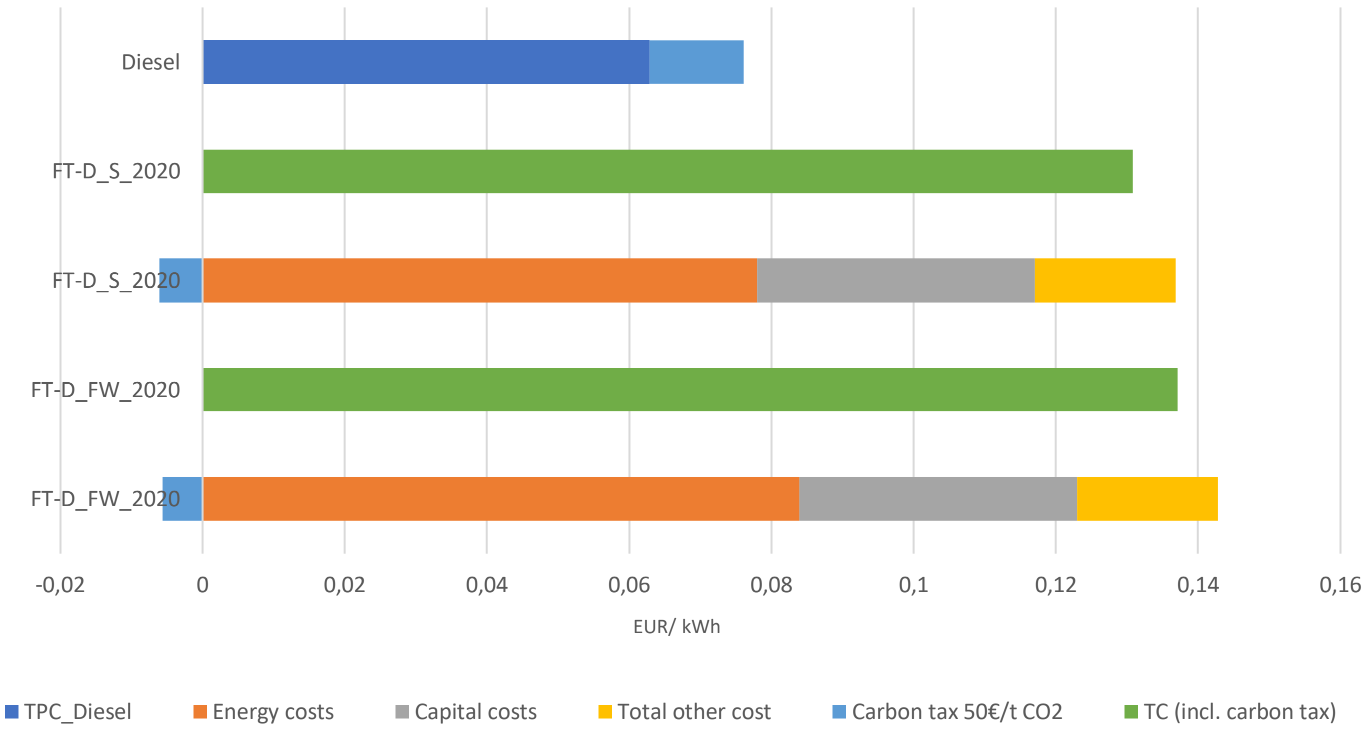

Fig. 1. Segmented total production costs for forest wood-to-FT diesel & straw-to-FT diesel chains incl. CO_2 taxes for 2020 (based on Ajanovic et al. 2012) compared to corresponding Diesel price (EUR/kWh) for the EU

*for the year 2020
Abbreviations:
TPC… total production cost, FT-D_FW…FT-diesel produced from forest wood, FT-D_S… FT-diesel produced from straw

Economic Assessment, BtL fuel chains (c) & (d)

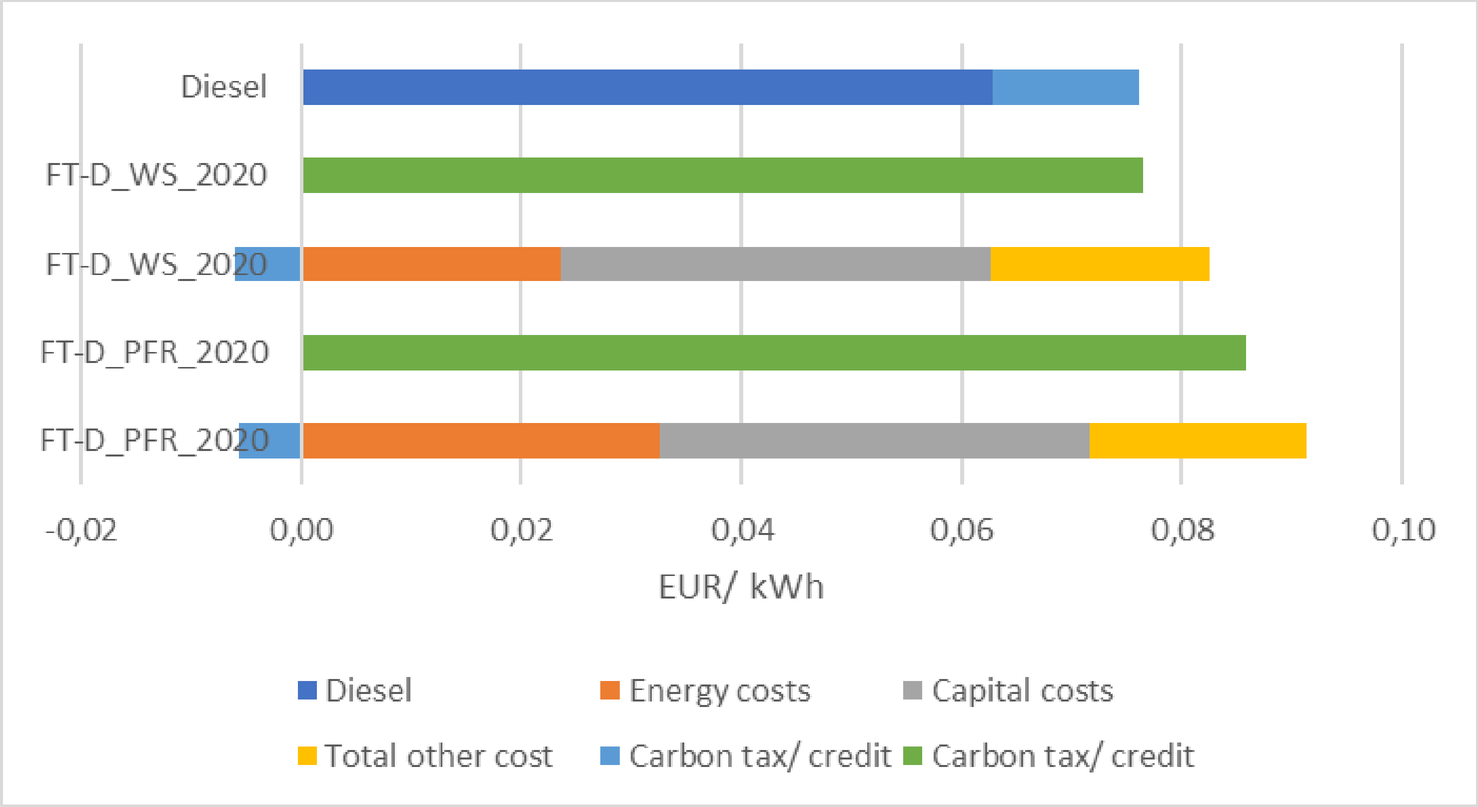

Fig. 2. Segmented total production costs for wheat straw-to-FT diesel & pine forest residues-to-FT diesel chains incl. CO_2 taxes for 2020 (based on CLARA project and Ajanovic et al. 2012) compared to corresponding Diesel price (€/kWh) for the EU

Abbreviations:
TPC… total production cost, FT-D_WS…FT-diesel produced from wheat straw, FT-D_PFR… FT-diesel produced from pine forest residues

Economic Assessment, 2030 & 2050 Outlook

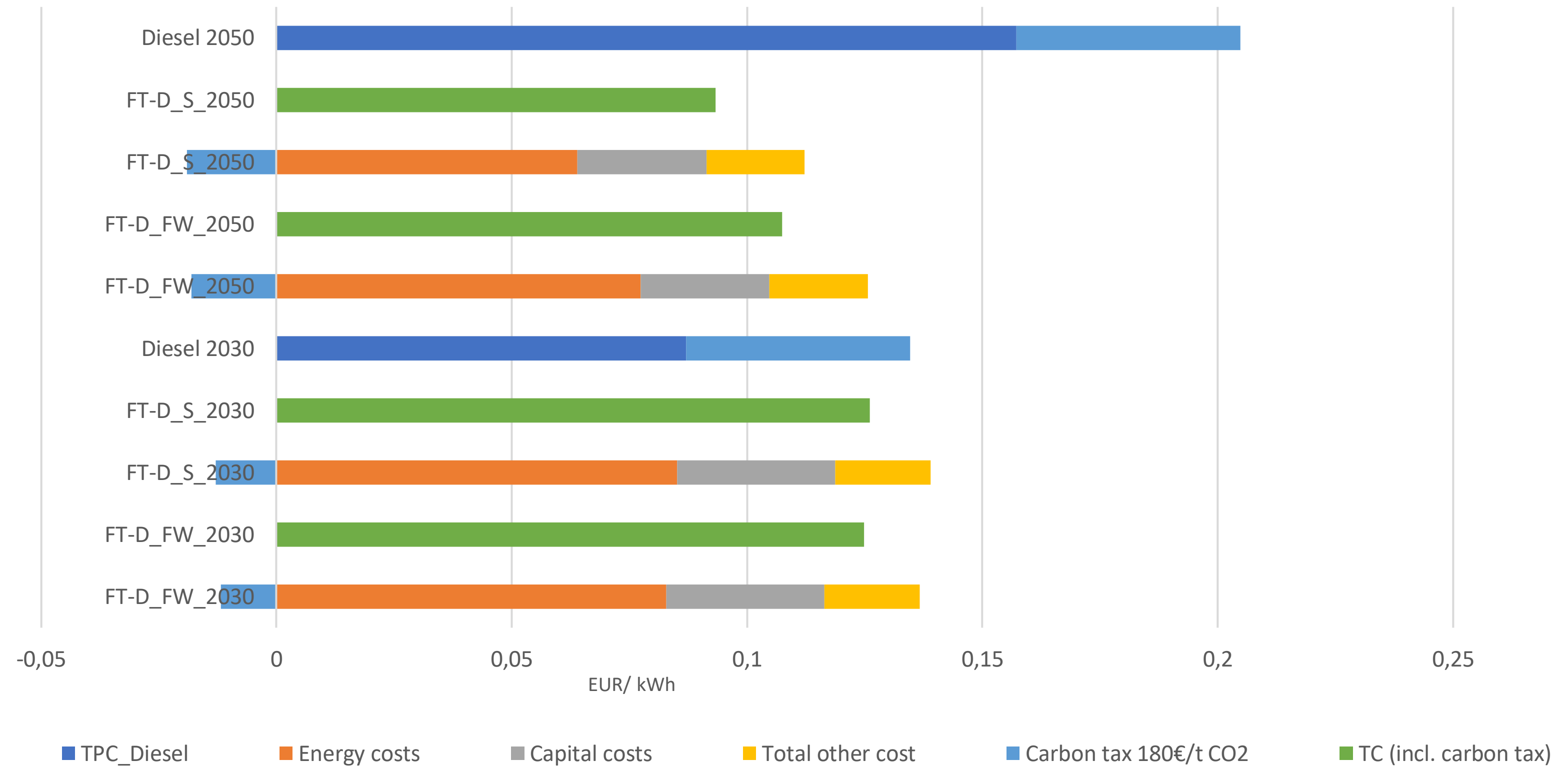

Fig. 3. Segmented total production costs scenarios for forest wood-to-FT diesel & straw-to-FT diesel chains incl. CO_2 taxes for 2030 and 2050 (based on Ajanovic et al. 2012) compared to corresponding Diesel prices (EUR/kWh) for the EU

Where FT-D_S and FT-D_FW signify FT diesel obtained from straw and forest wood, respectively, * Ajanovic et al (2012)

Environmental Assessment

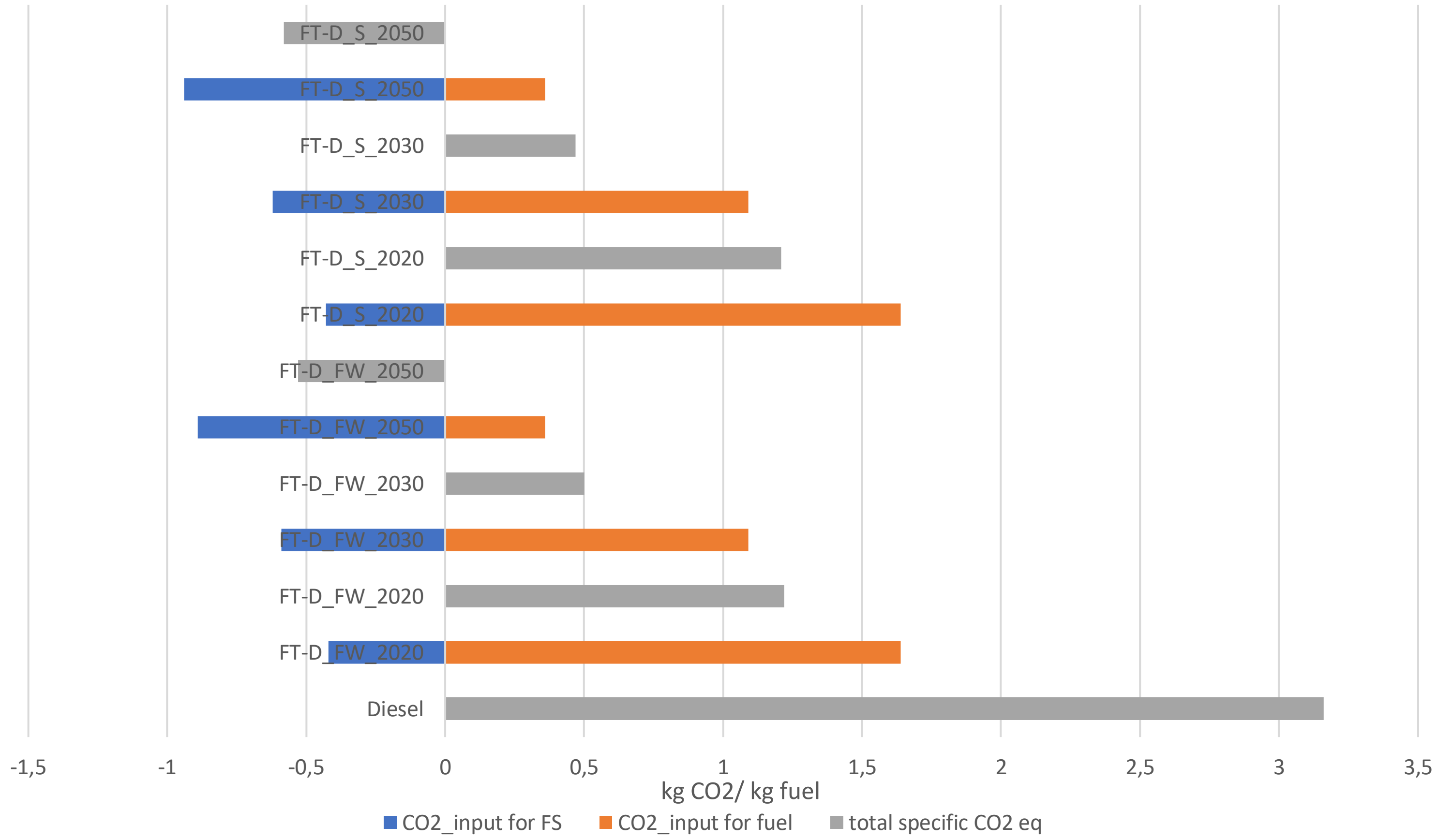

Fig. 4. CO_2 balances for forest wood-to-FT diesel & straw-to-FT diesel chains for 2020, 2030 and 2050 (based on Ajanovic et al. 2012) compared to corresponding Diesel CO_2 (TTW emissions) for the EU

Where FT-D_S and FT-D_FW signify FT diesel obtained from straw and forest wood, respectively, * Ajanovic et al (2012)

Outlook, selected major literature

Biomass Conversion and Biorefinery (2021) 11:2281–2292
https://doi.org/10.1007/s13399-019-00459-5

ORIGINAL ARTICLE

Check for updates

Fischer-Tropsch products from biomass-derived syngas and renewable hydrogen

Hannes Gruber[1,2] · Peter Groß[1] · Reinhard Rauch[2,3] · Alexander Reichhold[1] · Richard Zweiler[4] · Christian Aichernig[5] · Stefan Müller[6] · Nabeel Ataimisch[7] · Hermann Hofbauer[1,2]

Received: 29 March 2019 / Revised: 31 May 2019 / Accepted: 4 June 2019 / Published online: 22 June 2019

Abstract

Global climate change will make it necessary to transform transp
sustainable, flexible, and dynamic sector. A severe reduction of f
be necessary to keep global warming below 2 °C above prein
increase the share of renewable fuel consumed until alternative p
the share of renewables in the power generation sector grows wo
by fluctuating renewable sources is going to grow alike. The "
electricity combined with biomass-based fuel production. Surplu
The fluctuating H_2 source is combined with biomass-derived (
Fischer-Tropsch synthesis converts the syngas to renewable hy
performed and presents new insights regarding the effects of lo
paigns were carried out, and performance-indicating paramete
productivity were evaluated. The experiments showed that inte
concept could increase the productivity while product distributic
ment performed indicates good preconditions towards commerc

Keywords Fischer-Tropsch synthesis · BtL · Energy storage · Ex

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ELSEVIER

Techno-economic and uncertainty analysis of Biomass to Liquid (BTL) systems for transport fuel production

Check for updates

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BSTRACT

is work examines the technical and economic feasibility of Biomass-To-Liquid (BTL) processes for the man-
acture of liquid hydrocarbon fuels. Six BTL s
ygen gasification of woody biomass, and s
tion systems. Three fuel synthesis technolo
n followed by Methanol to Gasoline (MTG
Published modelling studies of BTL system
l production costs to assess economic via
eters. Unlike other studies, the present tec
certainty of key parameters on the fuel pr
alistic chance (8–14%) of concepts based on
at this probability could be increased to 50
t that deterministic estimates may be syste
The overall energy efficiency and producti
V and €17.88–25.41 per GJ of produced fue
corporates CFB gasification and FT synthes
sign indicate that a BTL process is not yet
ction costs are approximately 8% higher th
ssible in the long term through subsidies, c

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applied sciences

MDPI

Article

Process Control Strategies in Chemical Looping Gasification—A Novel Process for the Production of Biofuels Allowing for Net Negative CO_2 Emissions

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check for updates

Abstract: Chemical looping gasification (CLG) is a novel gasification technique, allowing for the production of a nitrogen-free high calorific synthesis gas from solid hydrocarbon feedstocks, without requiring a costly air separation unit. Initial advances to better understand the CLG technology were made during first studies in lab and bench scale units and through basic process simulations. Yet, tailored process control strategies are required for larger CLG units, which are not equipped with auxiliary heating. Here, it becomes a demanding task to achieve autothermal CLG operation, for which stable reactor temperatures are obtained. This study presents two avenues to attain autothermal CLG behavior, established through equilibrium based process simulations. As a first approach, the dilution of active oxygen carrier materials with inert heat carriers to limit oxygen transport to the fuel reactor has been investigated. Secondly, the suitability of restricting the air flow to the air reactor in order to control the oxygen availability in the fuel reactor was examined. Process simulations show that both process control approaches facilitate controlled and de-coupled heat and oxygen transport between the two reactors of the chemical looping gasifier, thus allowing for efficient autothermal CLG operation. With the aim of inferring general guidelines on how CLG units have to be operated in order to achieve decent synthesis gas yields, different advantages and disadvantages associated to the two suggested process control strategies are discussed in detail and optimization avenues are presented.

Keywords: chemical looping; biomass gasification; process control; process simulation

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"Drop-in" fuel production from biomass: Critical review on techno-economic feasibility and sustainability

Check for updates

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ARTICLE INFO

Keywords:
Biomass
"Drop-in" fuels
Techno-economic analysis
Life cycle assessment
Conversion technologies

ABSTRACT

This paper reviews the technological and economical feasibilities as well as sustainable assessment of approaches (thermochemical and biochemical) applied for sustainable "drop-in" fuel production from lignocellulosic sources. The challenges for each pathway to produce "drop-in" fuels are covered. Currently "drop-in" fuel production cost is approximately 2 times (~5–6$/gallon) higher than fossil fuels (3$/gallon), especially with the use of 2nd generation feedstocks. The primary sources of cost with "drop-in" fuel production are feedstock cost (40–60% of the total production cost), syngas cleaning and conditioning to meet Fischer-Tropsch synthesis requirement (12–15% of the total production cost) and bio oil upgrading (14–18% of the total production cost) in the case of pyrolysis and hydrothermal liquefaction (HTL). The most influential factors on the life cycle analysis (LCA) were biomass cultivation, harvesting, biomass pre-treatment, and transportation. Therefore, robust processes that can use local waste biomass are far more environmental and economically viable, especially as biofuel from second generation have a greater potential to reduce greenhouse gas emissions (50–100%) than first generation biofuels (50–90%) when land use changes are omitted in the LCA. The sustainability of biofuels is pre-dominantly dependant on the sustainability of the initial biomass, with 2nd generation feedstocks being more sustainable than 1st generation. Gasification-FTS is considered as the most promising technique for "drop-in" fuel production over pyrolysis and HTL due to its flexibility towards feedstock acceptance and the ability to produced high yields of liquid fuel together with other economically viable biofuels such as electricity and heat. Biochemical routes (i.e.fermentation) to "drop-in" fuels are still in their early development stages, and therefore require more studies and pilot-scale experiments in order to discover an economic and sustainable means of using these methods.

Conclusions

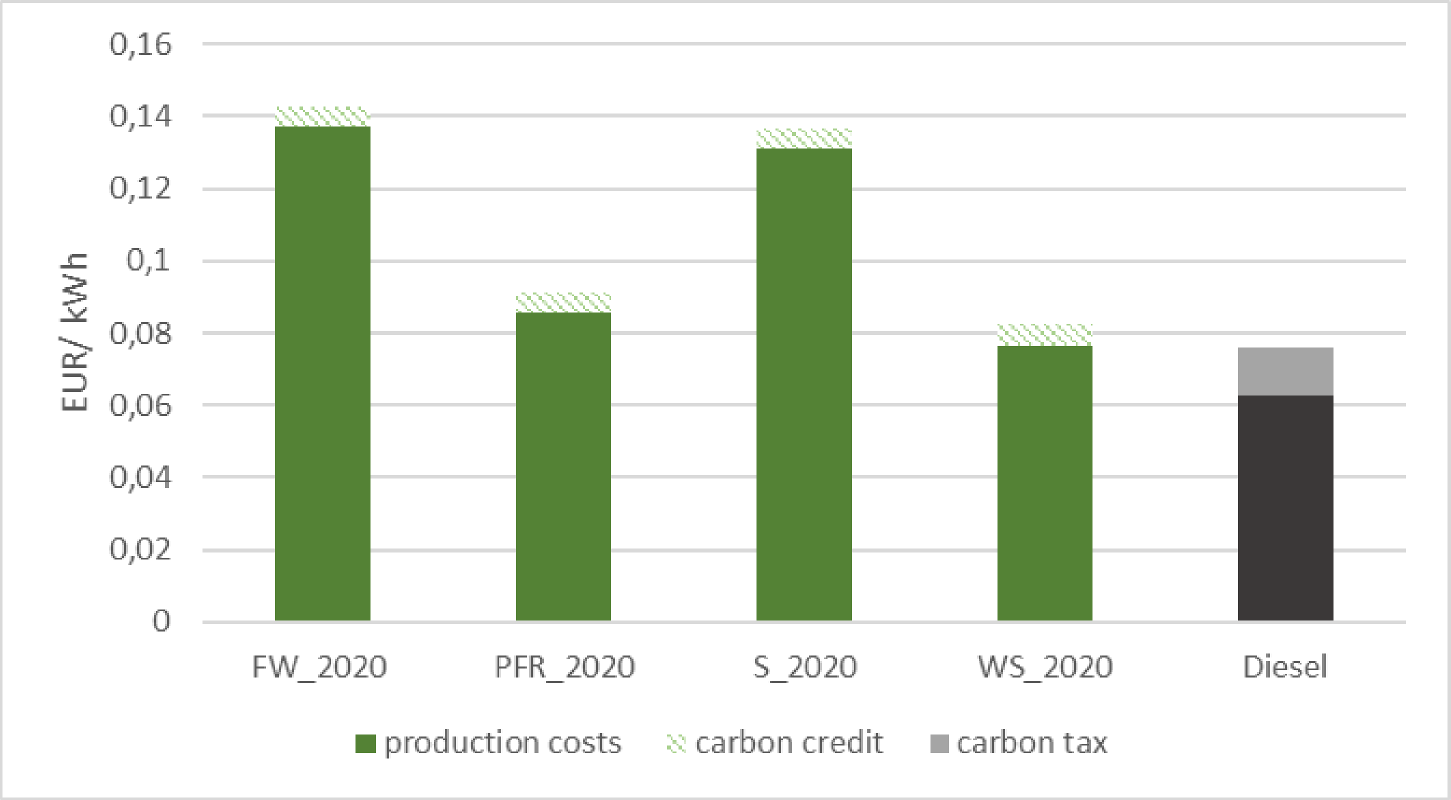

Fig. 5. Total production cost scenarios for forest wood-to-FT diesel (a), pine forest residue-to-FT diesel (c), straw-to-FT diesel (b) and wheat straw-to-FT diesel (d) chains incl. CO_2 taxes for 2020 (based on Ajanovic et al. 2012 & CLARA project) compared to corresponding Diesel prices (EUR/kWh) for the EU

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