Clean Techn Environ Policy (2013) 15:501–512
DOI 10.1007/s10098-013-0591-9

ORIGINAL PAPER

Hydrogen for oil refining via biomass indirect steam gasification: energy and environmental targets

Jean-Florian Brau · Matteo Morandin · Thore Berntsson

Received: 15 November 2012 / Accepted: 6 February 2013 / Published online: 18 February 2013

Abstract The energy and CO_2 consequences of substitution of a fossil-fuel-based hydrogen production unit with a biomass-based process in a large European refinery are studied in this study. In the base case, the biomass-based process consists in atmospheric, steam–blown indirect gasification of air-dried woody biomass followed by necessary upgrading steps. The effect of gradually substituting the current refinery hydrogen production unit with this process on global energy and CO_2 targets is estimated first. Few process concepts are studied in further detail by looking at different degrees of heat integration with the remaining refinery units and possible polygeneration opportunities. The proposed process concepts are compared in terms of energy and exergy performances and potential reduction in refinery CO_2 emission also taking into account the effect of marginal electricity. Compared to the base case, an increase by up to 8 % points in energy efficiency and 9 % points in exergy efficiency can be obtained by exploiting process integration opportunities. According to energy efficiency, steam production appears the best way to use excess heat available in the process while electricity generation through a heat recovery steam cycle appears the best option according to exergy efficiency results. All investigated cases yield to significant reduction in CO_2 emissions at the refinery. It appears in particular that maximal emission reduction is obtained by producing extra steam to cover the demand of other refinery units if high efficiency marginal electricity scenarios are considered.

J.-F. Brau (✉) · M. Morandin · T. Berntsson
Division of Heat and Power Technology, Department of Energy and Environment, Chalmers University of Technology, 412-96 Göteborg, Sweden
e-mail: jean-florian.brau@chalmers.se

Keywords Process integration · Hydrogen · Refinery · Energy systems · Simulation · Gasification

List of symbols

$e_{CO_2,i}$	Specific CO_2 emissions of fuel i (kg/GJ_{fuel})
$\dot{E}_{feedstock}$	Exergy in feedstock(s) (MW)
$\dot{E}_{H_2}$	Exergy in hydrogen output (MW)
el_{in}	Electricity input (MW)
el_{out}	Electricity output (MW)
$\dot{E}_{net\ electricity}$	Exergy in net electricity output (MW)
$\dot{E}_{steam}$	Exergy in steam output (MW)
Feedstock in	In Eq. (1), total energy in fuel input(s), on HHV basis (MW)
H_2	In Eq. (1), energy in hydrogen output, on HHV basis (MW)
HHV	Higher heating value (MJ/kg)
HP steam	High Pressure steam. In Eq. (1), energy in steam output (MW)
HT shift	Hight temperature water–gas shift reaction
LT shift	Low temperature water–gas shift reaction
$\dot{m}_{i,avoided}$	Mass flow of fuel avoided (kg/s)
η_{el}	Efficiency of marginal electricity producer
η_{ex}	Exergy efficiency
η_{tot}	First principle total efficiency
PSA	Pressure swing adsorption
SMR	Steam-methane reforming
ΔCO_2	Fossil CO_2 emission balance (kt/y)
ΔT	Temperature difference for heat exchange used in pinch analysis (°C)