Climate Performance of Ligno-cellulose-based Biofuels

Greenhouse gas performance of emerging production pathways for the biofuels ethanol, methanol, hydrogenated vegetable oil and methane

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Conclusions

- The criteria on greenhouse gas reduction stipulated in the EU Renewable Energy Directive is fulfilled by nine biofuel production pathways analysed in this study;
- Forest residues as feedstock shows lowest climate impact compared to cultivated biomass;
- Methanol, methane and ethanol production based on forest residues shows best climate performance followed by the production pathways of hydrogenated vegetable oils from residue tall oil and pyrolysis oil.

Introduction

According to amendments of the EU Renewable Energy Directive (RED 2009), biofuel production installations starting operation after October 2015 are required to present greenhouse gas (GHG) savings of at least 60% compared to the currently suggested fossil fuel reference of 83.8 g CO_2e MJ^{-1} fuel (EU 2015/1513). The objective of this study is to present updated calculations of the GHG performance of emerging ligno-cellulose-based biofuel production systems in the Swedish context. The considered biofuels are ethanol, methanol, hydrogenated vegetable oil (HVO) and methane based on feedstock from cultivated short-rotation coppice (willow), forest residues from foresting operations, black liquor from pulp and paper industry and straw from agricultural activities.

Table 1 – Results for nine biofuel production systems. DV signifies Default Value as outlined in the RED 2009, for comparison.

	HVO			Methanol			
values in g CO_2e MJ^{-1} biofuel	talloil	pyrolysis oil	waste vegetable or animal oil	forest resiudes	willow	waste wood	farmed wood
RED 2009			*DV*			*DV*	*DV*
cultivation / collection	3.6	4.9	0.0	1.9	13.2	1.0	5.0
processing / conversion	1.2	1.2	13.0	0.0	0.0	0.0	0.0
transport / distribution	1.3	1.7	1.0	1.1	1.0	4.0	2.0
total GHG emissions	**6.2**	**7.8**	**14.0**	**3.0**	**14.2**	**5.0**	**7.0**
GHG savings	**93%**	**91%**	**83%**	**96%**	**83%**	**94%**	**91%**

	Ethanol						Methane	
values in g CO_2e MJ^{-1} biofuel	straw	forest resiudes	willow	straw	farmed wood	waste wood	forest resiudes	willow
RED 2009				*DV*	*DV*	*DV*		
cultivation / collection	0.9	1.8	12.6	3.0	6.0	1.0	1.6	10.8
processing / conversion	9.8 [a]	2.2 [b]	2.2 [b]	7.0	17.0	17.0	0.9	0.9
transport / distribution	0.5	0.9	0.9	2.0	2.0	4.0	2.4	2.3
total GHG emissions	**11.1**	**5.0**	**15.7**	**13.0**	**25.0**	**22.0**	**4.8**	**14.0**
GHG savings	**87%**	**94%**	**81%**	**85%**	**70%**	**74%**	**94%**	**83%**

a: off-site enzyme production; b: on-site enzyme production

Method

The method used to evaluate the climate performance of the biofuel production pathways is in line with the GHG calculation method as suggested in the RED (2009). Calculations include emissions from the extraction or cultivation as well as the collection of feedstock, emissions from processing and conversion as well as emissions from transport and distribution. The climate impact is expressed in gram carbon dioxide equivalent (CO_2e) per Mega Joule (MJ) of the biomass-based fuel (LHV). Technology-specific data from previous research and industry collaborations is applied.

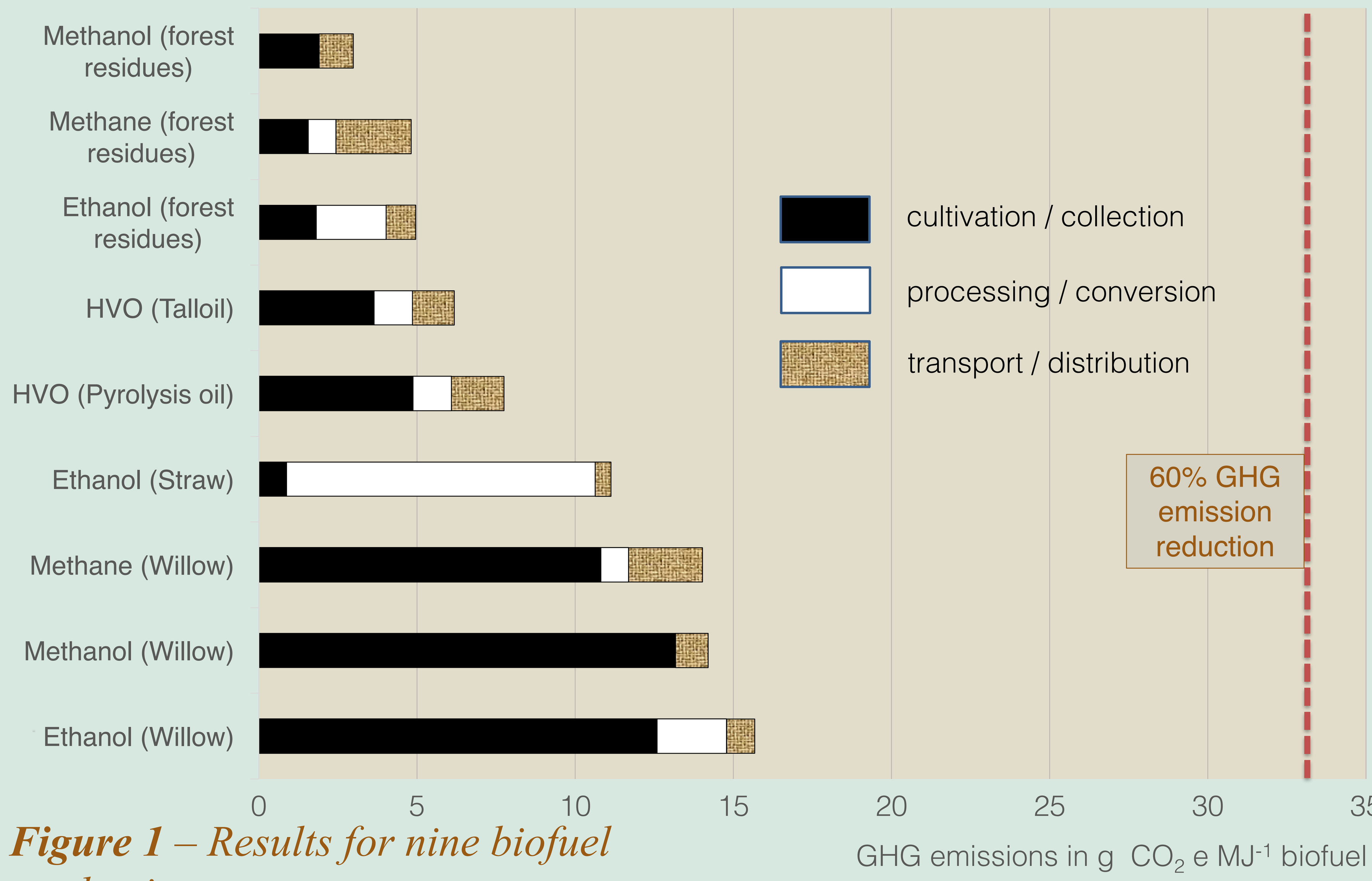

Figure 1 – Results for nine biofuel production systems.

Results

Since the configuration of RED's (2009) calculation method excludes emissions prior to the extraction of residue biomass, the policy is explicitly in favour of these biofuel production systems making use of forest residues, black liquor and straw. Thus, the residue based production pathways of methanol, methane, and ethanol showed lowest climate impact (<5 g CO_2e MJ^{-1}), followed by the production pathways of HVO from residue tall oil and pyrolysis oil. For the ethanol production pathway, the energy demand of the off-site enzyme production burdens the biofuels total climate performance with an approximate amount of 10 g CO_2e MJ^{-1}; this impact can be significantly moderated by an on-site enzyme preparation based on the feedstock. The cultivation of feedstock accounts for a significant part (>10 g CO_2e MJ^{-1}) of the biofuels' total GHG emissions (see Table 1 and Figure 1). However, it could be seen that GHG savings for all investigated feedstock and pathways are between 81 – 96% (see Table 1), implying that the emerging ligno-cellulose-based production pathways, considered in this study, can be suitable for future biofuel supply, even under a regime imposing more rigid sustainability criteria (> 60%) and changed fossil fuel reference.

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