Hydrothermal Co-Carbonization of Sewage Sludge and Lignocellulosic Biomass in the Perspective of the Life Cycle Assessment

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Motivation

Ultimately, the main aim of this work is to identify how the addition of biomass to the hydrothermal carbonization of sewage sludge implemented at the wastewater treatment facility changes the process impact on the environment. To achieve this aim, three scenarios are proposed:

I. In the first scenario a typical, considerably large, wastewater treatment plant is considered. After anaerobic digestion, the sewage sludge is dewatered, dried and thermally utilized;

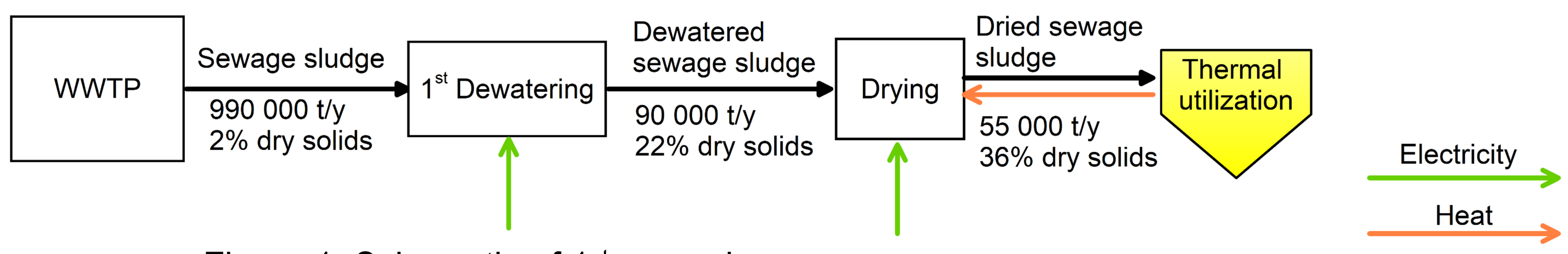


Figure 1. Schematic of 1st scenario.

II. In the second scenario, after anaerobic digestion hydrothermal carbonization of sewage sludge is introduced, after that hydrochar is dewatered, dried, and combusted;

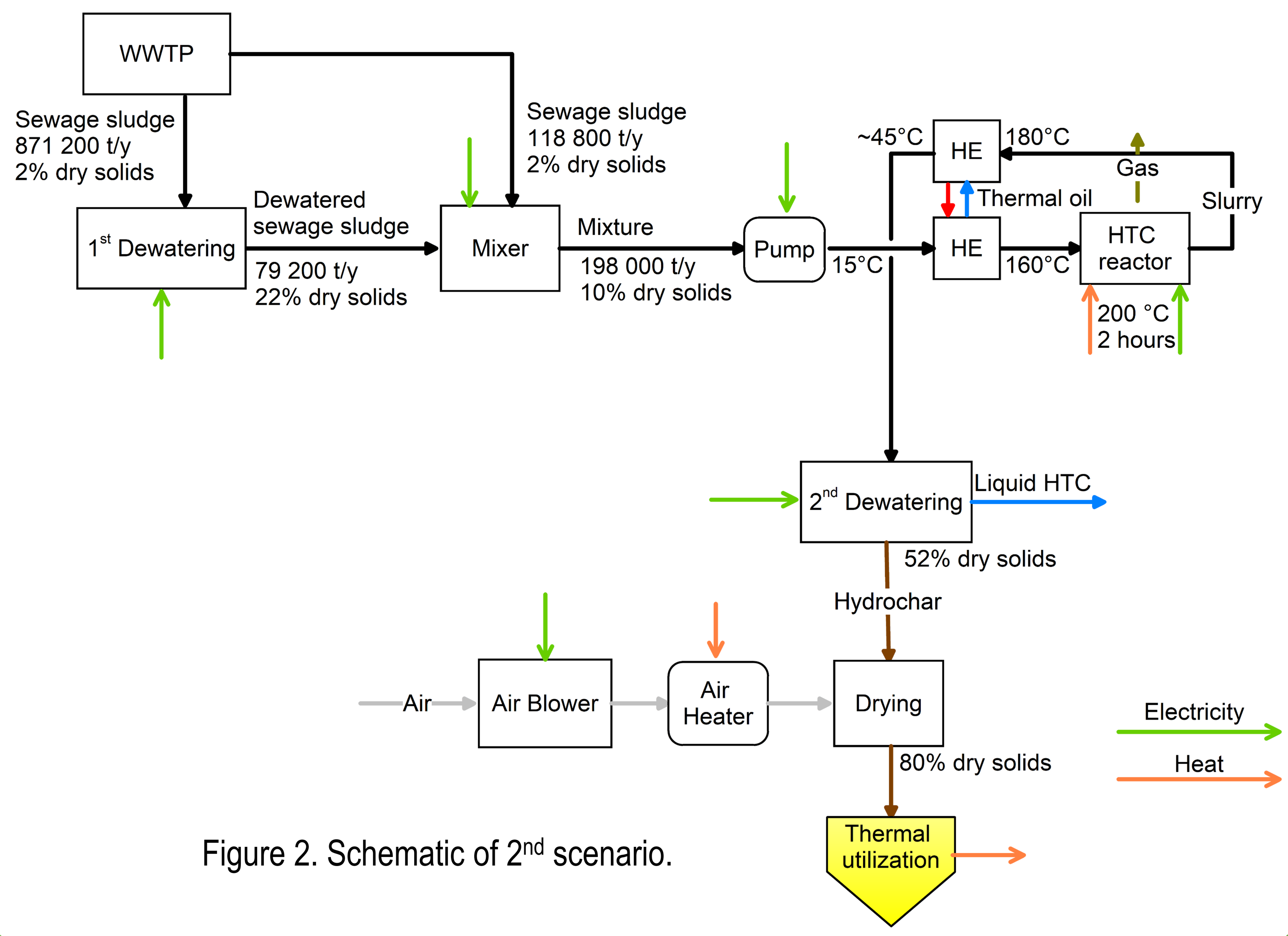


Figure 2. Schematic of 2nd scenario.

III. The third scenario is analogical to the second scenario, but sewage sludge is mixed with fir sawdust (80%/20% on dry mass basis) and then submitted to HTC reactor.

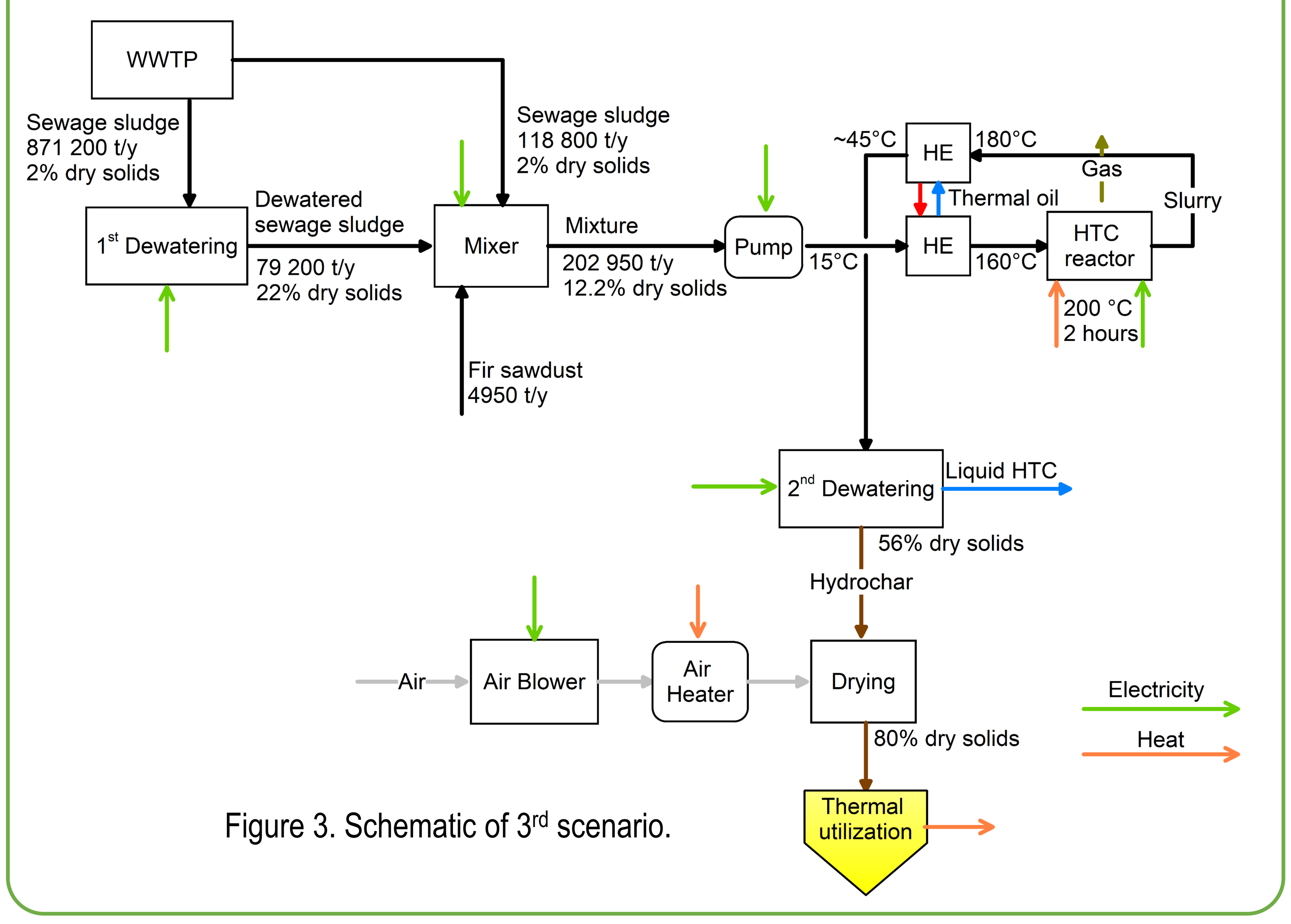


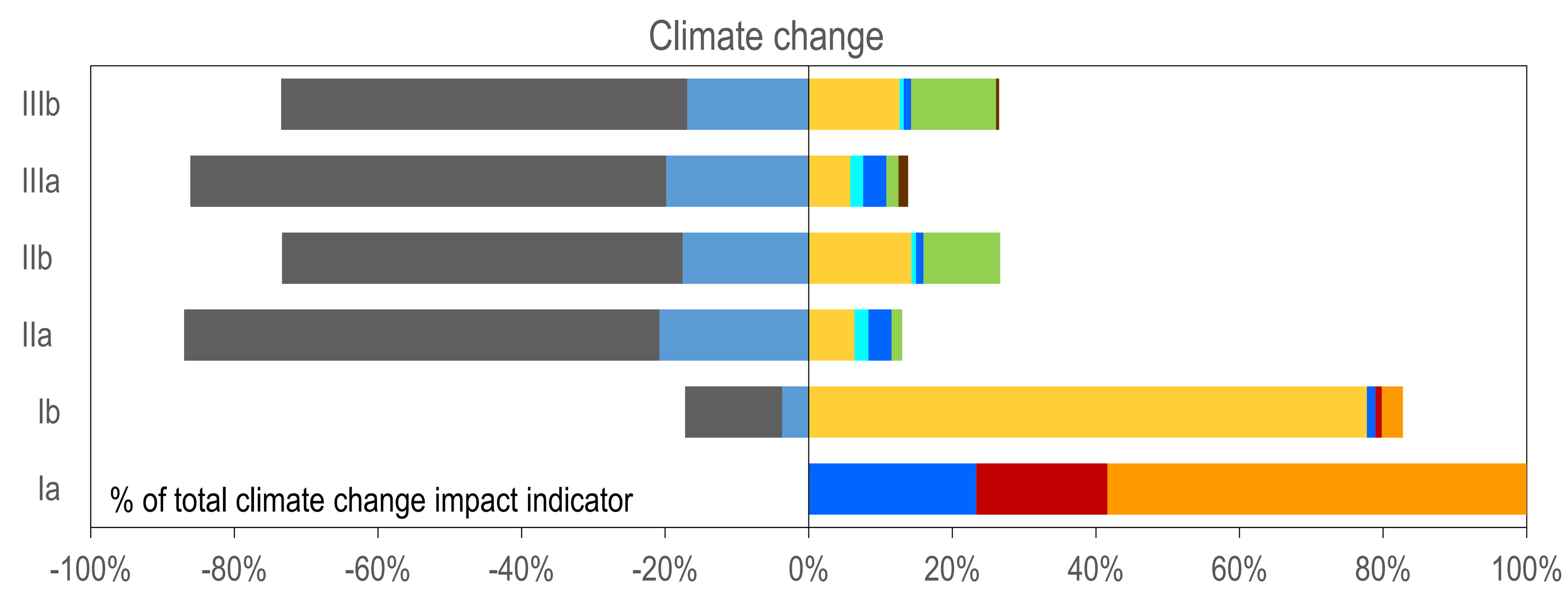
Figure 3. Schematic of 3rd scenario.

Materials and Methods

In each scenario two pathways for sludge and hydrochar thermal utilization were considered. The first one, marked with letter a, assumes thermal utilization onsite, that will allow to provide energy required for HTC process or for drying of the sewage sludge (Ia). The remaining hydrochar is assumed to replace lignite (on lower heating value basis) in nearby power plant. The second pathway, marked with letter b, assume that all of SS or HC is sent for thermal utilization in that nearby power plant. In these variants thermal energy is produced from combustion of natural gas. The emissions from SS, HC or lignite combustion in power plant are assumed to be the same, as they depend mainly on the flue gas treatment system. An exception is CO_2 emissions, because lignite's CO_2 emissions are avoided, while CO_2 emission from SS or HC combustion have biogenic origin and are assumed not to contribute to climate change.

Table 1. Inventory data expressed per functional unit (1 t of SS_{db}).

	units	Ia	Ib	IIa	IIb	IIIa	IIIb
Mass flow of feedstock, ar	t/y	90 000	90 000	198 000	198 000	202 950	202 950
Mass flow of solid fraction, db	kg/h	2 475	2 475	2 475	2 475	3095	3095
Thermal energy demand	kWh/t	57.05	5895.94	1312.04	1312.04	1456.74	1456.74
Electrical energy demand	kWh/t	62.00	300.96	50.81	50.81	53.83	53.83
Lower heating value, db	MJ/kg	12.36	12.36	14.29	14.29	15.49	15.49
Thermal energy produced from HC	kWh/t	-	-	2382	2382	2582.2	2582.2
HC combusted onsite	kg/t	-	-	367.21	-	376.1	-
NO_x emissions from SS/HC combustion onsite	kg/t	1.91E-01	-	1.17E-01	-	9.03E-02	-
CO emissions from SS/HC combustion onsite	kg/t	1.54E-02	-	1.95E-03	-	1.53E-01	-
PM_{10} emissions from SS/HC combustion onsite	kg/t	1.54E-03	-	7.84E-03	-	5.22E-02	-
SO_2 emissions from SS/HC combustion onsite	kg/t	1.03E-02	-	9.60E-01	-	7.99E-01	-
Avoided lignite combustion	kg/t	-	129.64	159.19	410.3	165.97	444.78
Avoided CO_2 emissions	kg/t	-	282	-	774	-	882



Climate change, kg CO_2/t	Ia	Ib	IIa	IIb	IIIa	IIIb
Avoided impacts		-76.87	-94.39	-243.28	-98.41	-263.73
Lignite emissions		-281.60	-300.30	-774.00	-329.13	-882.00
Drying		1617.49	28.91	198.22	28.76	197.21
WWTP			8.78	8.78	8.86	8.86
Dewatering	24.43	24.43	14.61	14.61	16.09	16.09
HTC reactor			6.56	147.70	8.20	184.45
HTC pretreatment			0.08	0.08	0.17	0.17
Sawdust					6.70	6.70
Thermal energy	19.17	19.17				
Electric energy	61.21	61.21				
Total	**104.81**	**1363.82**	**-335.75**	**-647.89**	**-358.76**	**-732.26**

Figure 4. Impact of presented scenarios on climate change expressed per functional unit (1 t of SS_{db}).

Summary

In Figure 4 a summary of calculated climate change impact indicator is presented. Positive values represent the environmental load, while negative values are the beneficial effects. In scenario Ib drying SS to 80% dry solids content has high energy demand. This result in scenario Ib being the least favourable. In other scnearios „b" heating reactor with natural gas allowed for avoiding larger amount of combusted fossil fuels in the power plant in comparison to scenarios IIa and IIIa. Complete Life Cycle Assessment will allow to better understand impact of proposed scenarios on the environment

Acknowledgements

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