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Environmental comparison of different scenarios of energy recovery from organic fraction of municipal solid waste and sewage sludge

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Outline

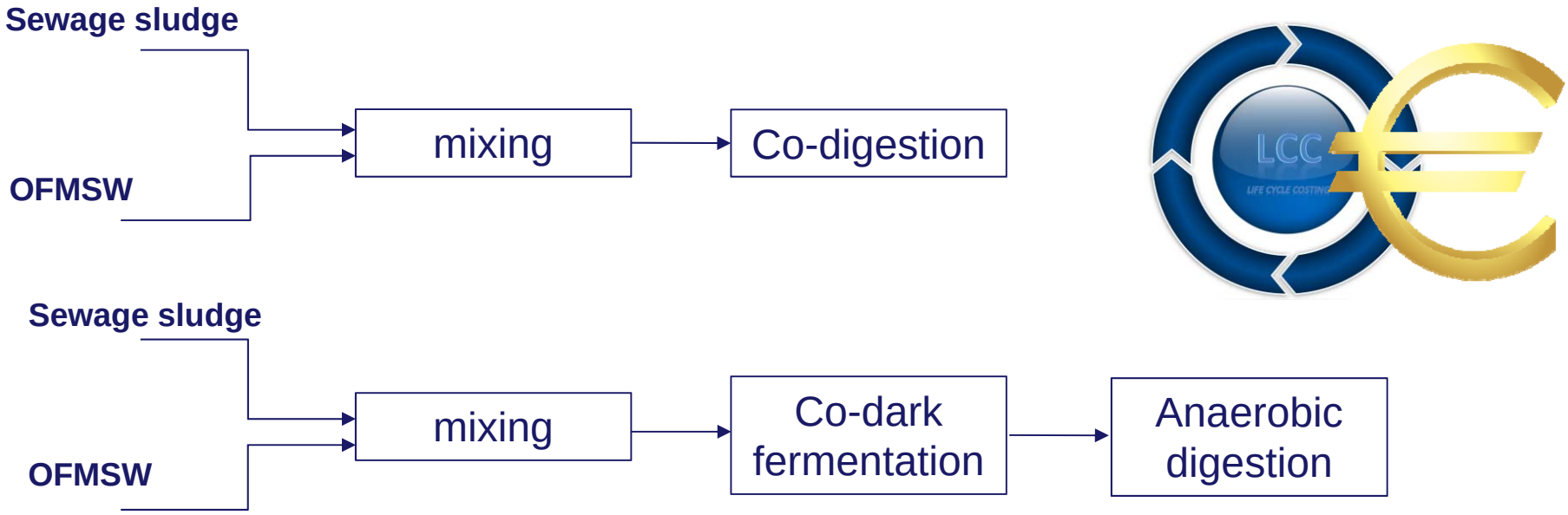
- Introduction
- LCA: goal and scope definition
- LCA: inventory
- LCA: impact assessment
- LCA: impact assessment/sensitivity
- Conclusions

Introduction

Co-digestion: WWTP digesters' potential

Bio2Energy

Dark fermentation as preliminary stage (H_2)



Goal and scope definition

- **Comparison of 3 scenarios:**

- **reference scenario:** aerobic bio-stabilisation of SS-OFMSW and anaerobic digestion of SS

- **Scenario #1:** co-digestion of SS-OFMSW and SS

- **Scenario #2:** preliminary co-dark-fermentation of SS-OFMSW and SS + AD

- **Functional unit:**

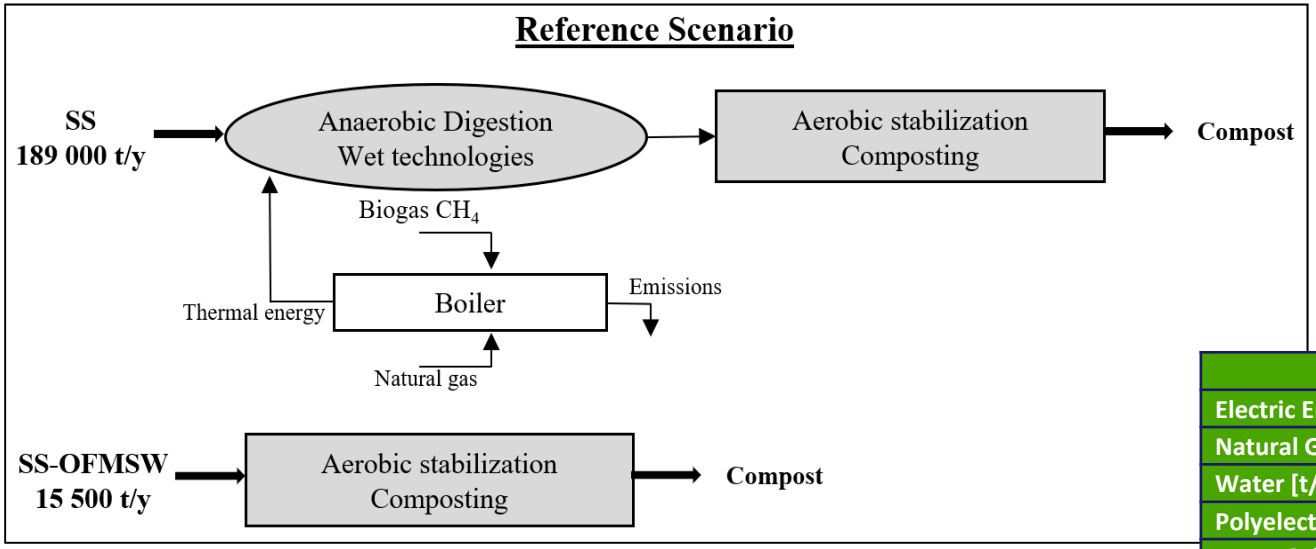
189 000 t/y of SS
(0.7% TS, 70% TVS)

+

15 500 t/y
of SS-OFMSW
(37 % TS, 68% TVS)

SS-OFMSW	%
Organic food	67.28
Organic (non-food)	2.72
Paper	3.60
Cardboard	6.00
High density plastics	2.00
Plastics films	6.00
Textile materials	0.40
Glass	4.00
Ferrous metals	1.00
Non-ferrous metals	1.00
Hazardous	1.00
Inert	5.00

Inventory – Ref scenario



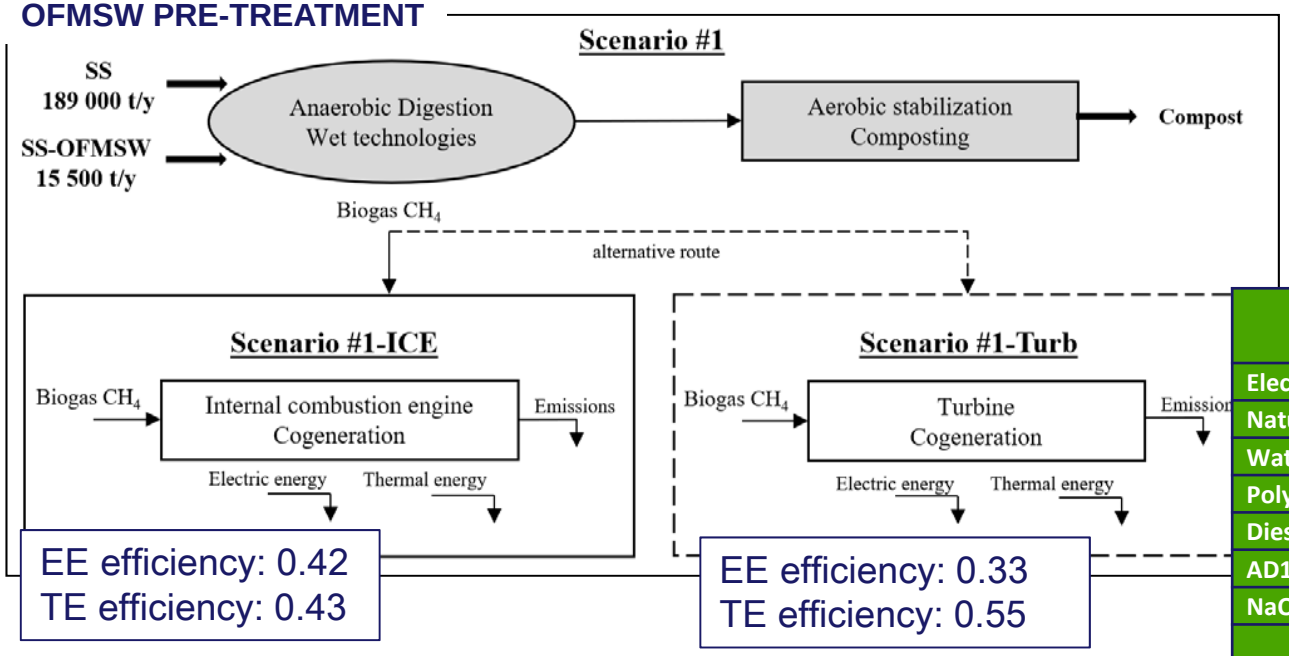
	N (as TKN) [g/kgTS]	P (as P_2O_5) [g/kgTS]	K (as K_2O) [g/kgTS]
Dry Digestate/compost	50	40	4
SS-OFMSW Compost	18	30	18.5

	Compost use
Gardens (peat)	25 %
Mineral fertilisers	68 %
Reclamations	7 %

Input	Reference Scenario
Electric Energy [MWh/y]	1438
Natural Gas [MWh/y]	630
Water [t/y]	4100
Polyelectrolyte [t/y] *	14
Diesel [t/y]	17.03
NaOH [t/y] *	0.5
Output	
Electric Energy [MWh/y]	-
Thermal Energy [MWh/y]	-
Compost [t/y]	5930
Supernatant [t/y]	175 929
Waste [t/y]	5365
NO_x [t/y]	0.779
CO [t/y]	0.234
Biogenic CO_2 [t/y]	665
PM [t/y]	0.021
SO_2 [t/y]	0.142

Inventory - #1 scenario

OFMSW PRE-TREATMENT



4:1 OFMSWTVS:SSTVS

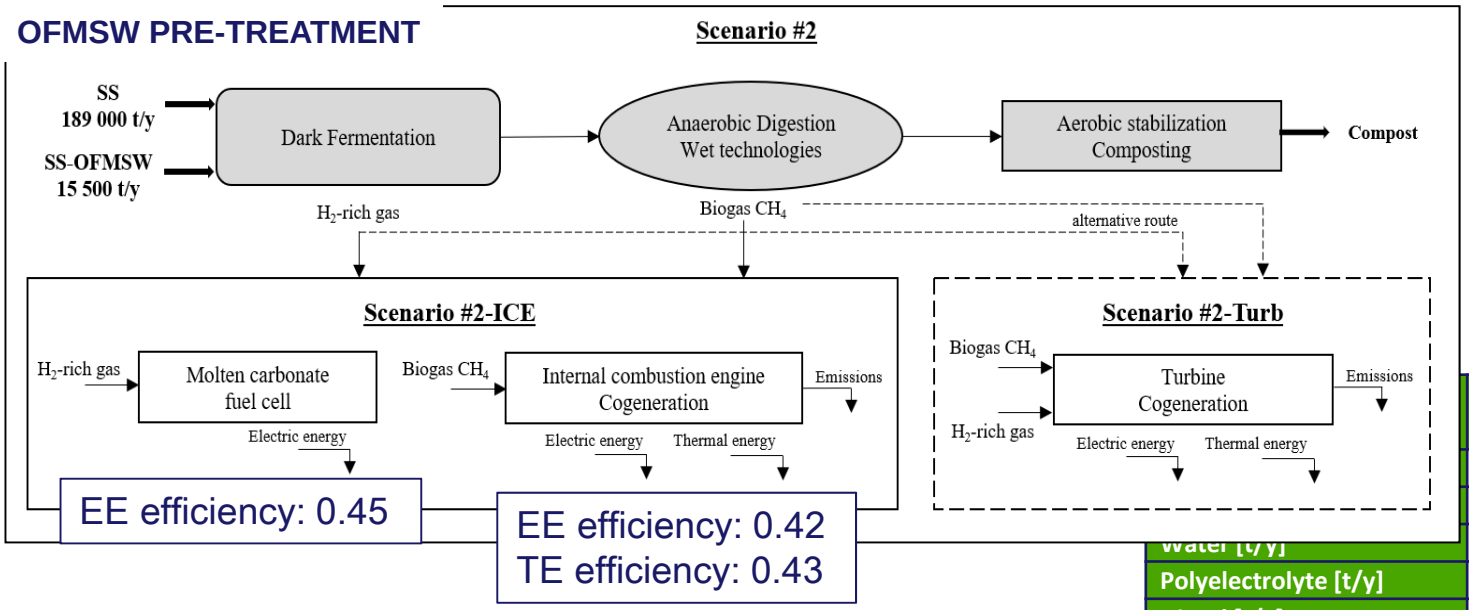
EE efficiency: 0.42
TE efficiency: 0.43

EE efficiency: 0.33
TE efficiency: 0.55

Parameters	Values
Volume	4500 m^3
HRT	20.69 d
OLR	1.95 kg TVS/m^3 d
SGP (SS)	0.289 Nm^3 biogas/kg TVS
SGP (SS-OFMSW)	0.678 Nm^3 biogas/kg TVS
Biogas produced	5540 Nm^3/d
Volumetric composition of biogas	65% CH_4 0.5% H_2S 32% CO_2 2.5% H_2O
LHV biogas	22 750 kJ/Nm^3

Input	Scenario #1-ICE	Scenario #1-Turb
Electric Energy [MWh/y]	196	196
Natural Gas [MWh/y]	-	-
Water [t/y]	4100	4100
Polyelectrolyte [t/y]	19	19
Diesel [t/y]	16.91	16.91
AD13 [t/y]	3.5	3.5
NaOH [t/y]	1	1
Output		
Electric Energy [MWh/y]	2523	1518
Thermal Energy [MWh/y]	2348	3473
Compost [t/y]	2223	2223
Supernatant [t/y]	181 541	181 541
Waste [t/y]	5313	5313
NO_x [t/y]	0.458	0.033
CO [t/y]	1.519	0.183
Biogenic CO_2 [t/y]	2526	2526
PM [t/y]	0.035	0.138
SO_2 [t/y]	0.982	0.982

Inventory - #2 scenario



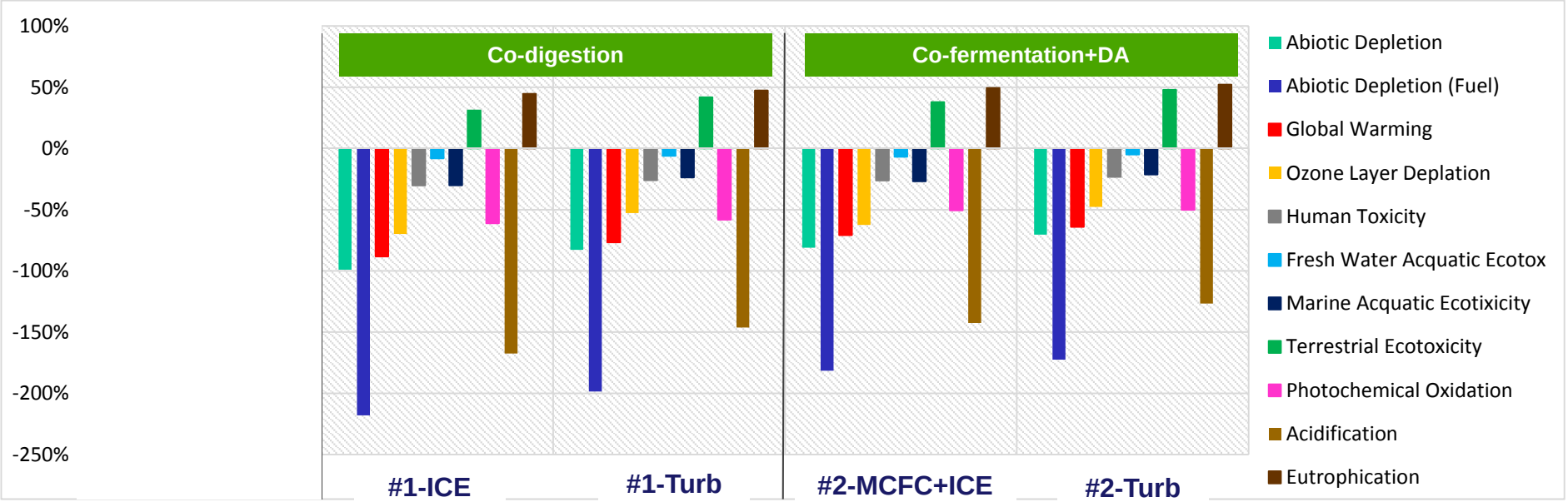
EE efficiency: 0.33
TE efficiency: 0.55

Parameters	Values
Volume	818 m^3
HRT	3.8 d
OLR	10.73 kg TVS/m^3 d
SGP (both SS and SS-OFMSW)	0.06 m^3 biogas/kg TVS
Hydrogen-rich gas produced	526.5 Nm^3/d
Volumetric composition of hydrogen-rich gas	45% H_2 65% CO_2
LHV hydrogen-rich gas	5 735 kJ/Nm^3

	Scenario #2-MCFC+ICE	Scenario #2-Turb
	185	185
	-	-
Water [t/y]	4100	4100
Polyelectrolyte [t/y]	18	18
Diesel [t/y]	16.91	16.91
AD13 [t/y]	3	3
NaOH [t/y]	1	1
Output		
Electric Energy [MWh/y]	2183	1215
Thermal Energy [MWh/y]	1279	2811
Compost [t/y]	2099	2099
Supernatant [t/y]	181 767	181 767
Waste [t/y]	5313	5313
NO_x [t/y]	0.422	0.030
CO [t/y]	1.399	0.169
Biogenic CO_2 [t/y]	2330	2330
PM [t/y]	0.032	0.127
SO_2 [t/y]	0.904	0.904

Impact assessment

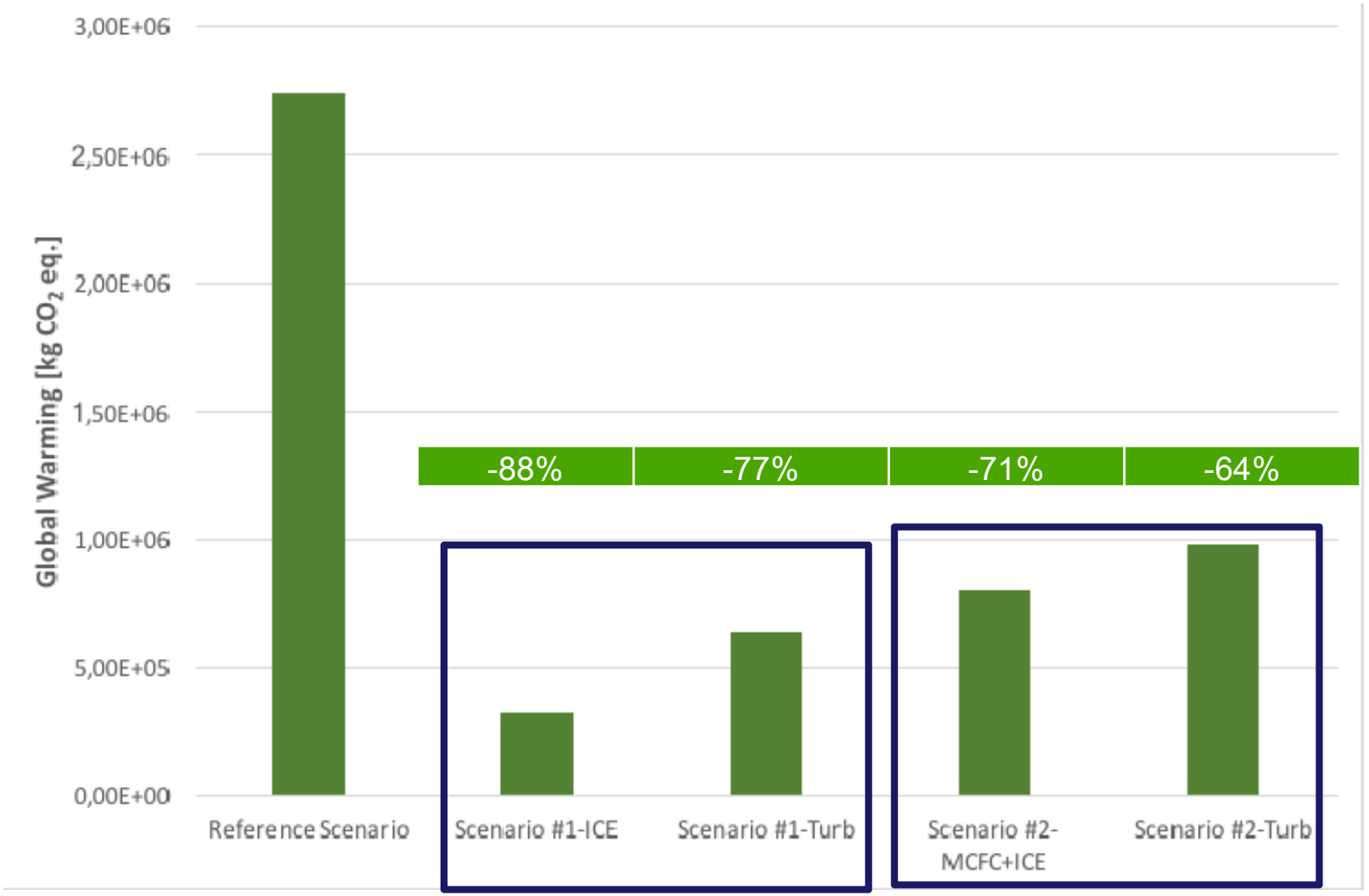
CML-IA baseline V3.02 / EU25 method



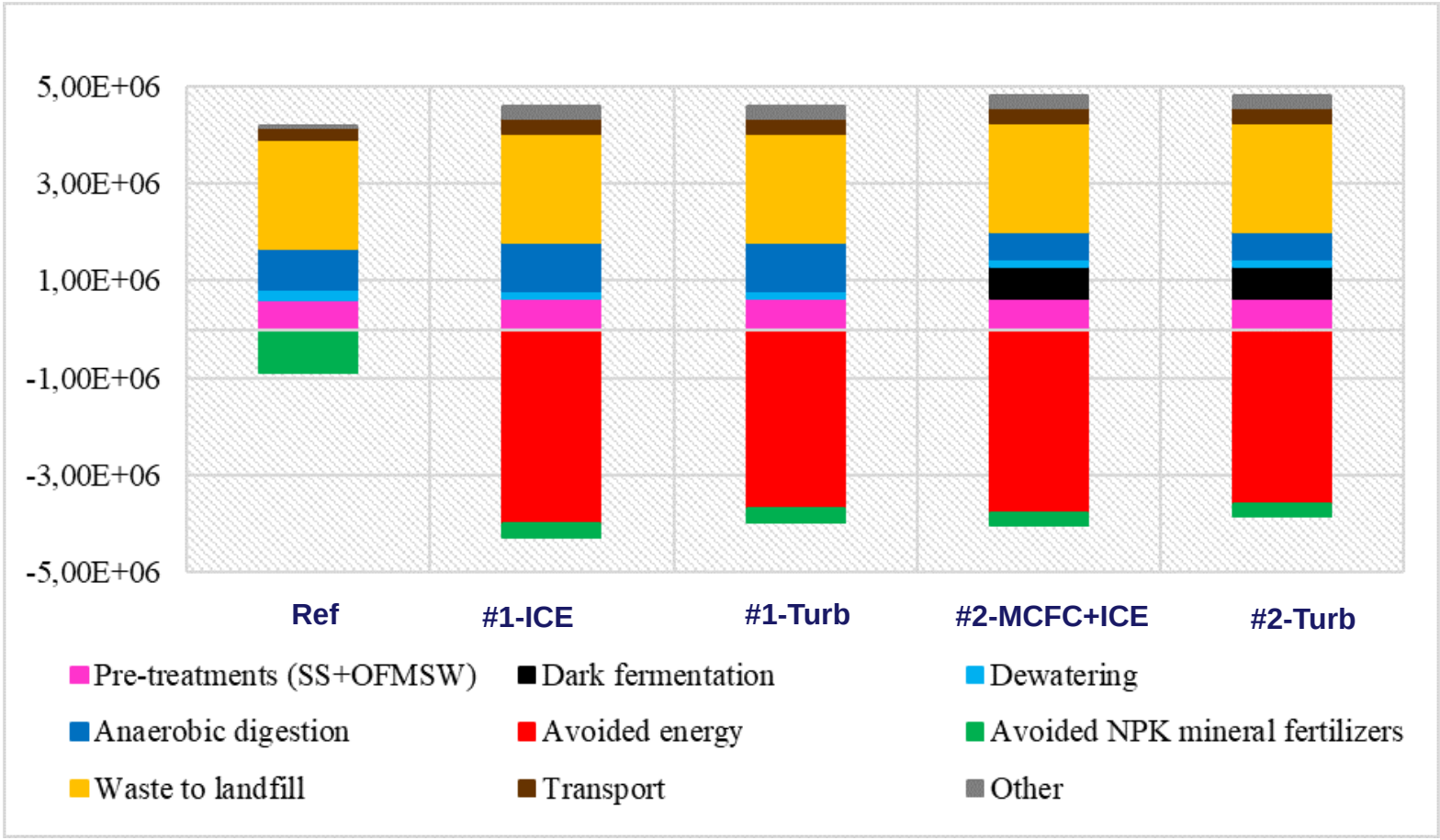
Percentage change

$$PC = \frac{I_n - I_{ref}}{I_{ref}} \cdot 100 \ (n = 1; 2)$$

Impact assessment

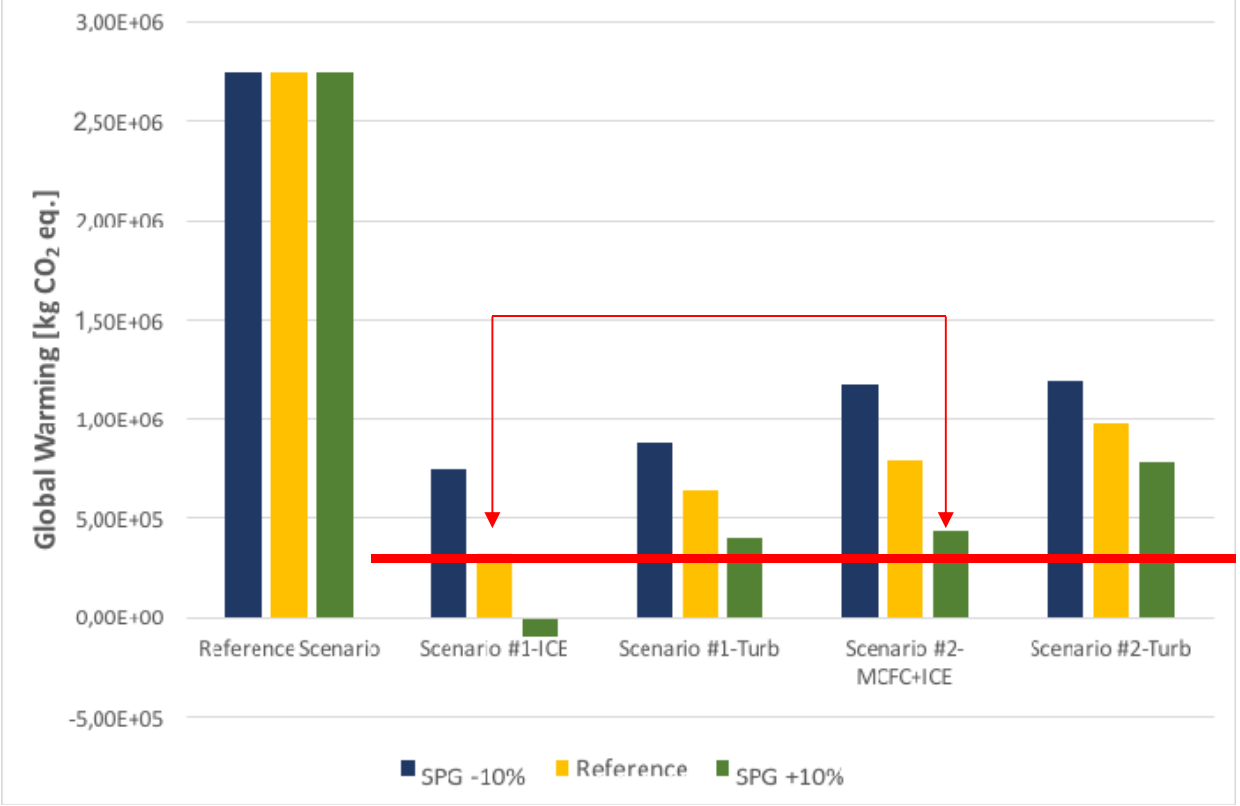


Impact assessment

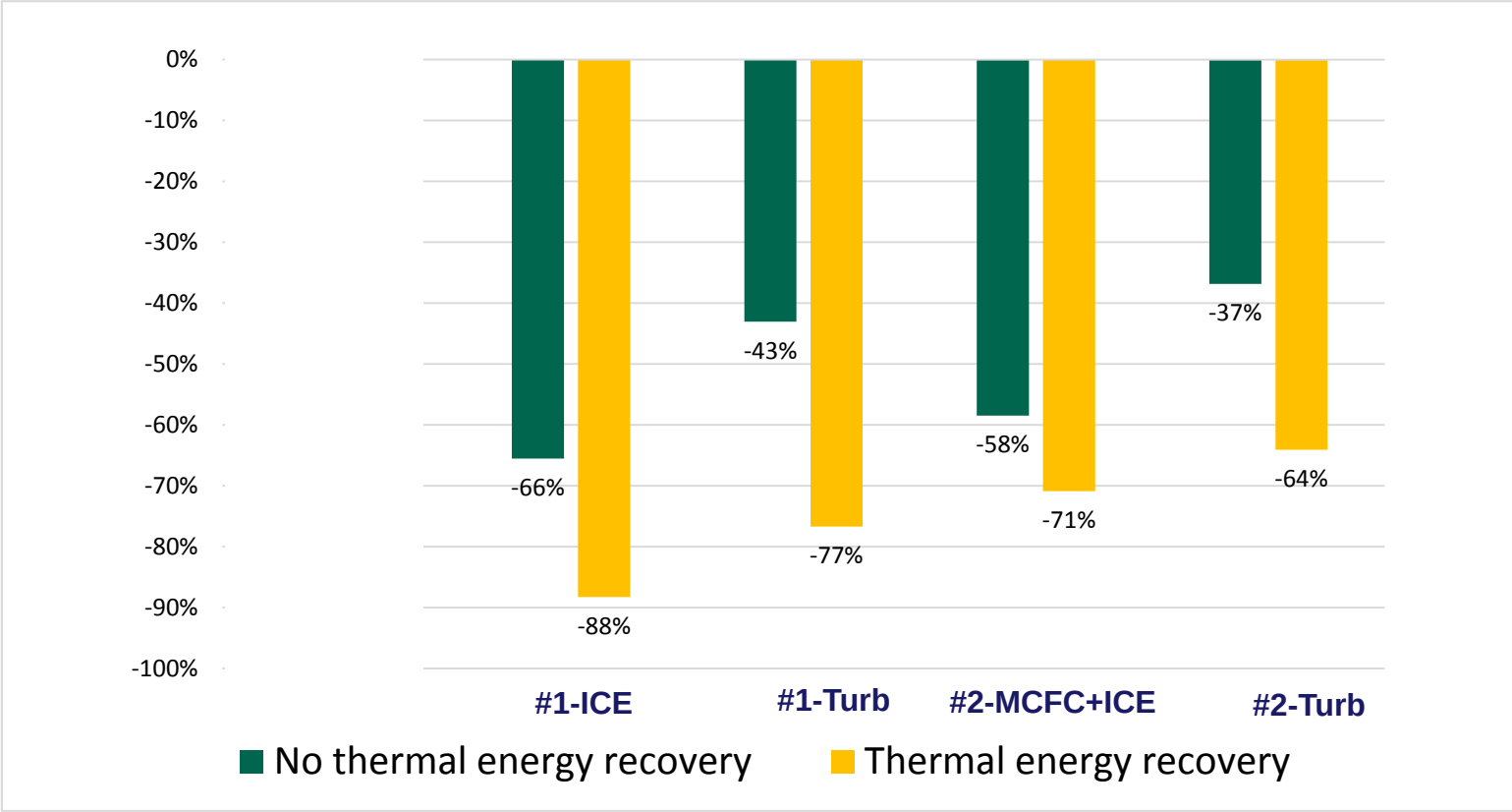


Sensitivity analysis

	Decrease -10%	Reference value	Increase +10%
Anaerobic digestion SGP [Nm^3 biogas/kgTVS]	0.568	0.631	0.694
Dark fermentation SGP [Nm^3 biogas/kgTVS]	0.054	0.06	0.066



Sensitivity analysis



Conclusions

- Co-digestion improves the performances with respect to the conventional situation
- Also co-dark-fermentation+AD improves the performances with respect to the conventional situation
- Co-digestion > co-dark-fermentation
- ICE > Turbine
- SPG is key parameter

Thank you!