UABIO

Carbon intensity of biomethane for different raw materials and production technologies

June 12, 2025

Volodymyr Kramar, Ph.D.,
expert of the Bioenergy Association of Ukraine.

Basic methodological principles

REDII & RED III: DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the promotion of the use of energy from renewable sources (recast):

https://eur-lex.europa.eu/eli/dir/2018/2001/oj/eng

ANNEX VI. Rules for calculating the greenhouse gas impact of biomass fuels and their fossil fuel comparators.

$$E = \sum_{l}^{n} S_n \cdot \left(e_{ec,n} + e_{td,feedstock,n} + e_{l,n} - e_{sca,n}\right) + e_p + e_{td,product} + e_u - e_{ccs} - e_{ccr} \quad (1)$$

$$S_n = \frac{[P_n \cdot W_n]}{\sum_1^n [P_n \cdot W_n]} \quad (2)$$

E = total emissions from the production of the biogas or biomethane before energy conversion;

S_n = Share of feedstock n, in fraction of input to the digester;

$e_{ec,n}$ = emissions from the extraction or cultivation of feedstock n;

$e_{td,feedstock,n}$ = emissions from transport of feedstock n to the digester;

$e_{l,n}$ = annualised emissions from carbon stock changes caused by land-use change, for feedstock n;

e_{sca} = emission savings from improved agricultural management of feedstock n;

e_p = emissions from processing;

$e_{td,product}$ = emissions from transport and distribution of biogas and/or biomethane;

e_u = emissions from the fuel in use, that is greenhouse gases emitted during combustion;

e_{ccs} = emission savings from CO_2 capture and geological storage; and

e_{ccr} = emission savings from CO_2 capture and replacement.

S_n = Share of feedstock n in energy content

P_n = energy yield [MJ] per kilogram of wet input of feedstock n

W_n = weighting factor of substrate n

$$W_n = \frac{I_n}{\sum_1^n I_n} \cdot \left(\frac{1 - AM_n}{1 - SM_n}\right) \quad (3)$$

I_n = Annual input to digester of substrate n [tonne of fresh matter]

AM_n = Average annual moisture of substrate n [kg water/kg fresh matter]

SM_n = Standard moisture for substrate n (***)

Basic methodological principles

$$SAVING = \frac{E_{F(t)} - E}{E_{F(t)}}, \quad (4)$$

$E_{F(t)}$ – total emissions from the fossil fuel comparator for transport, equal to **94 g CO_2-eq/MJ**

*The desired level of reductions for biofuels, biogas consumed in the transport sector is **65%** → **E_{max} = 32.9** g CO2-eq/MJ*

Lists of material eligible for ISCC EU certification (01 April 2025): Process to determine if a material meets the definition for waste and residues

1. Is the material an end product that the production process directly seeks to produce or a primary aim of the production process? — YES → (Co-)Product

   NO ↓

2. Was the material intentionally modified or contaminated to meet the definition of a "waste", e.g. by adding a waste to a product and thus turning the product into a waste? — YES → Critical Non-Compliance/Fraud

   NO ↓

3. Does the holder discard, intend to, or is the holder (legally) required to discard the material? — YES → Waste

   NO ↓

4. Is the material directly generated by agriculture, aquaculture, fisheries or forestry? — YES → Agricultural, Aquaculture, Fisheries or Forestry Residue

   NO ↓

Processing Residue

For products

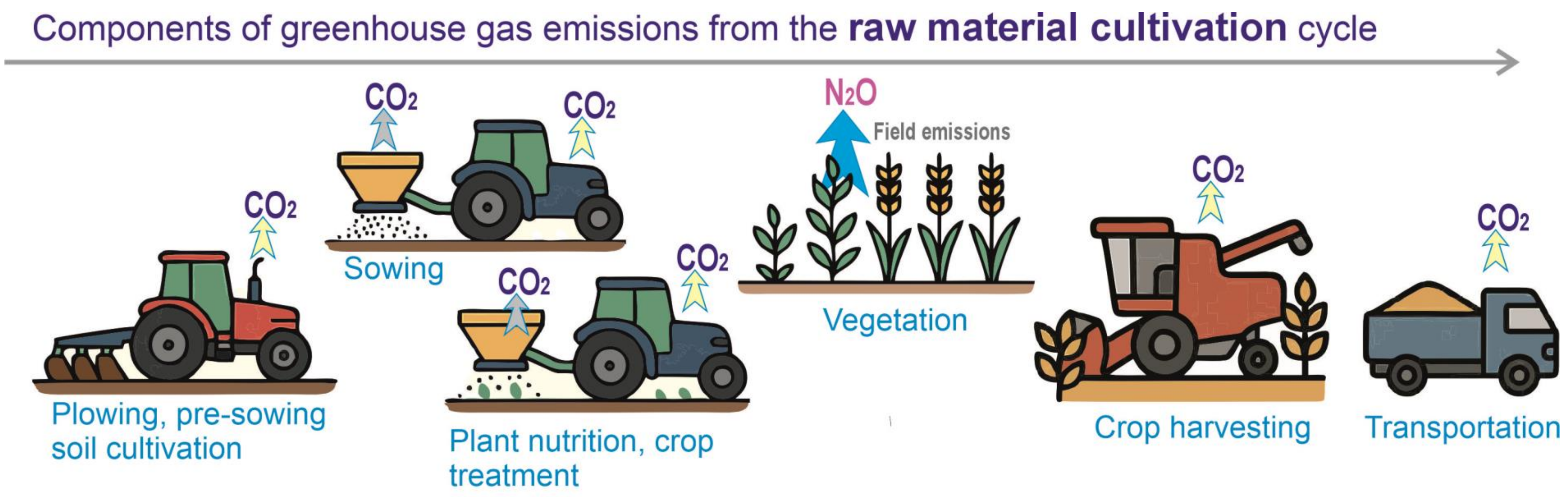
$$e_{ec}\left[\frac{kg\ CO_2eq}{ton}\right] = \frac{\left(EM_{fertiliser} + EM_{N2O} + EM_{inputs} + EM_{fuel} + EM_{electricity}\right)\left[\frac{kg\ CO_2eq}{ha * yr}\right]}{yield\ raw\ material\ \left[\frac{ton}{ha * yr}\right]} \quad (5)$$

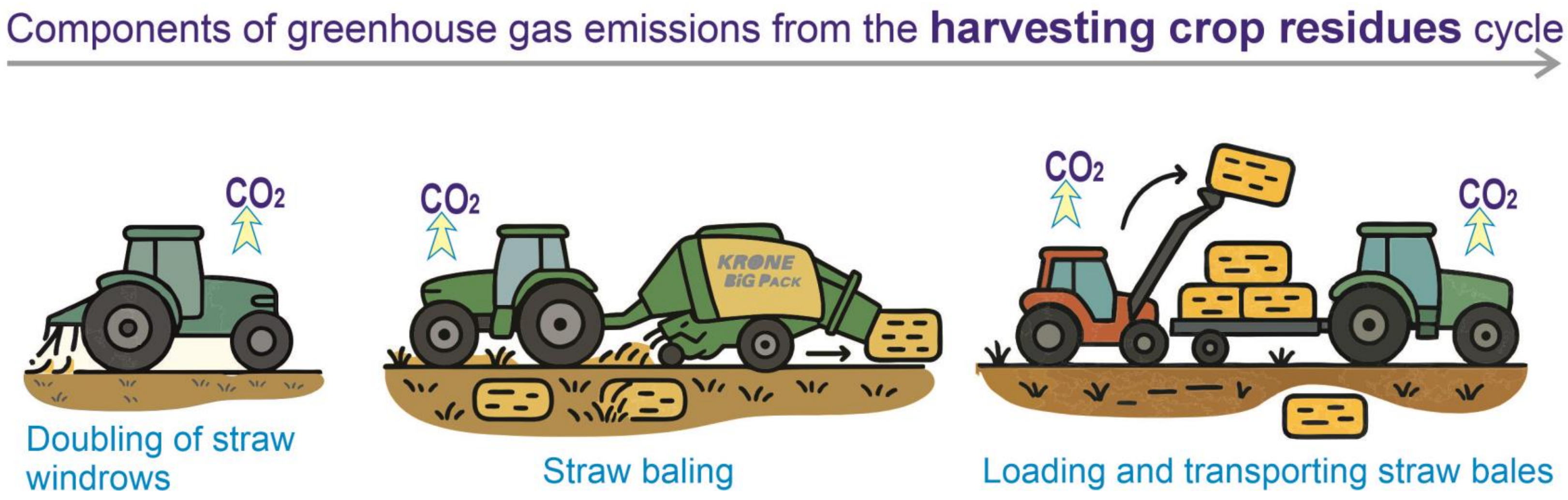
$$EM_{fertiliser} = fertiliser\ input\ \left[\frac{kg\ nutrient}{ha * yr}\right] * EF_{production}\left[\frac{kg\ CO_2eq}{kg\ nutrient}\right] \quad (6)$$

$$e_{td}\left[\frac{kg\ CO_2eq}{ton}\right] = \frac{T_{needed} * \left(d_{loaded}[km] * K_{loaded}\left[\frac{l}{km}\right] + d_{empty}[km] * K_{empty}\left[\frac{l}{km}\right]\right) * EF_{fuel}\left[\frac{kg\ CO_2eq}{l}\right]}{amount\ transported\ material\ [ton]} \quad (7)$$

$$EM_{electricity} = electricity\ consumption\ \left[\frac{kWh}{ha * yr}\right] * EF_{electricity}\left[\frac{kg\ CO_2eq}{kWh}\right] \quad (8)$$

Products or Residues – what is the difference?

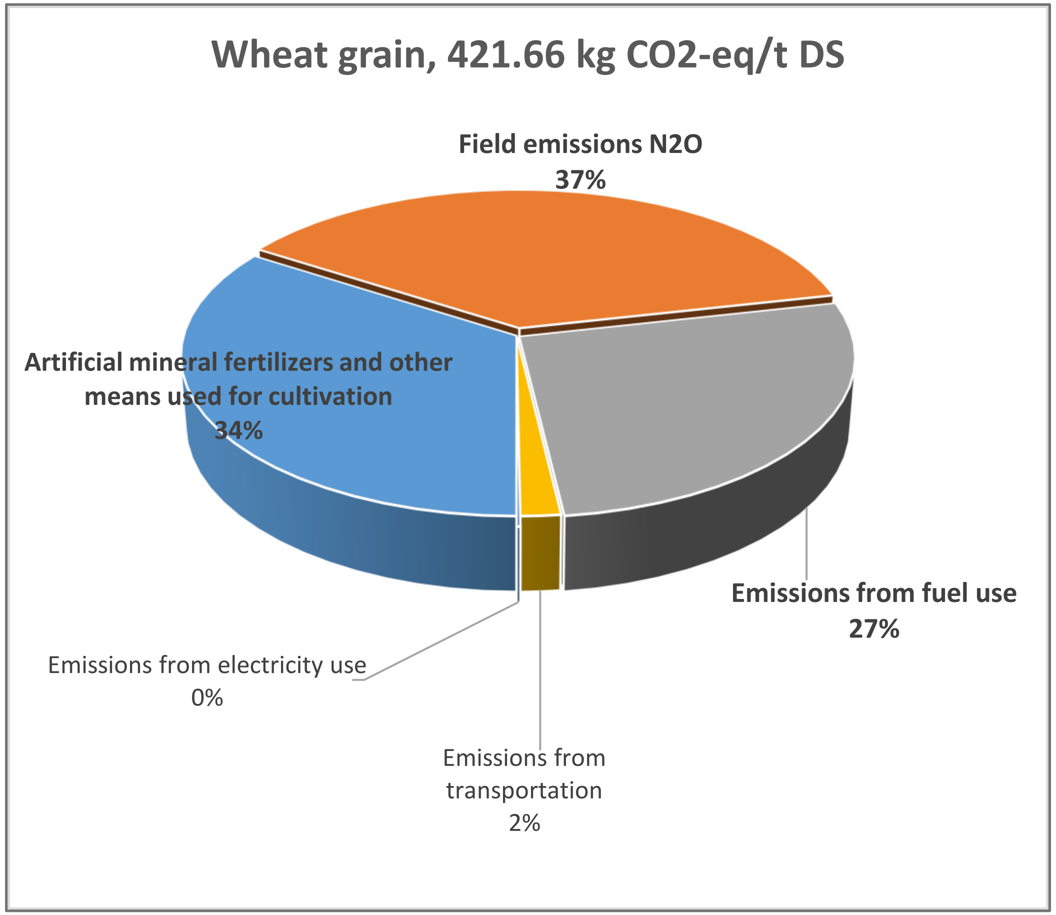


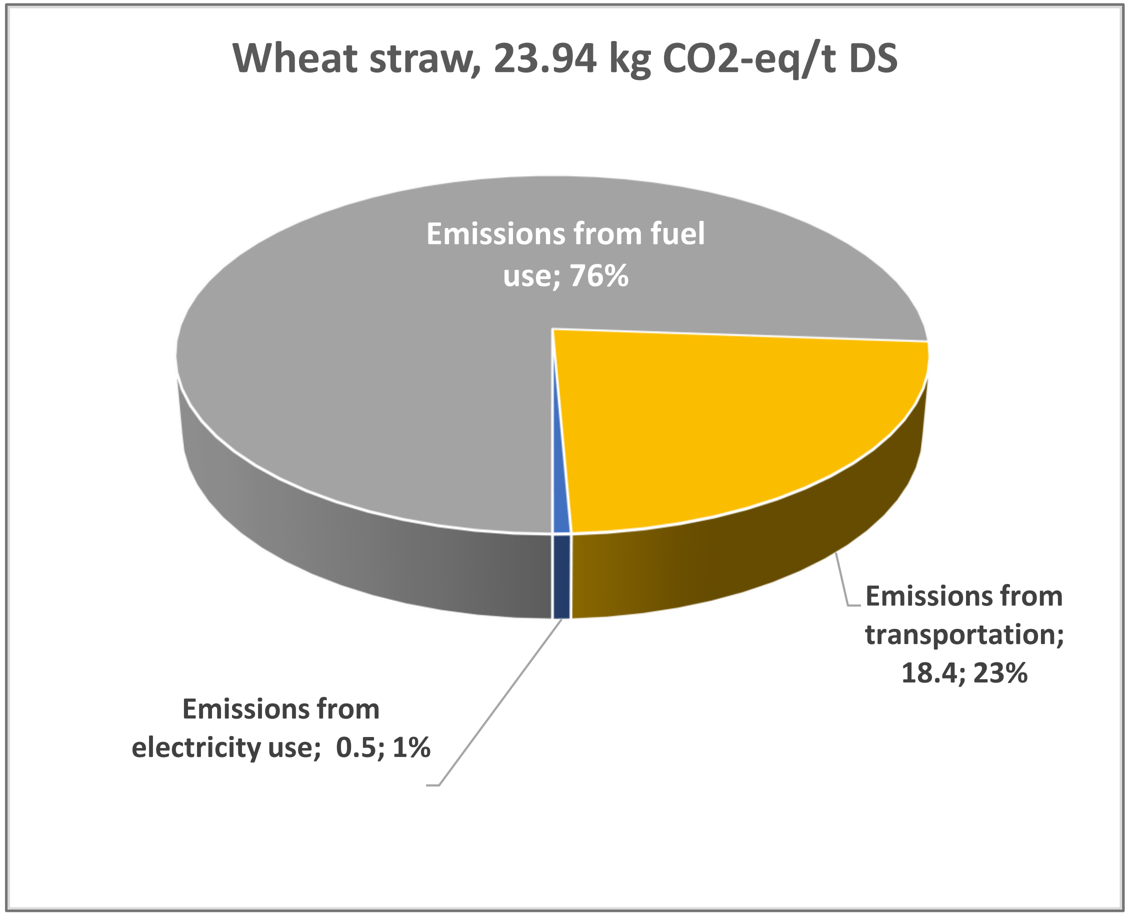


Ratios: kg CO2-eq/ 1 kg of emission		
CO_2	CH_4	N_2O
1	25	298

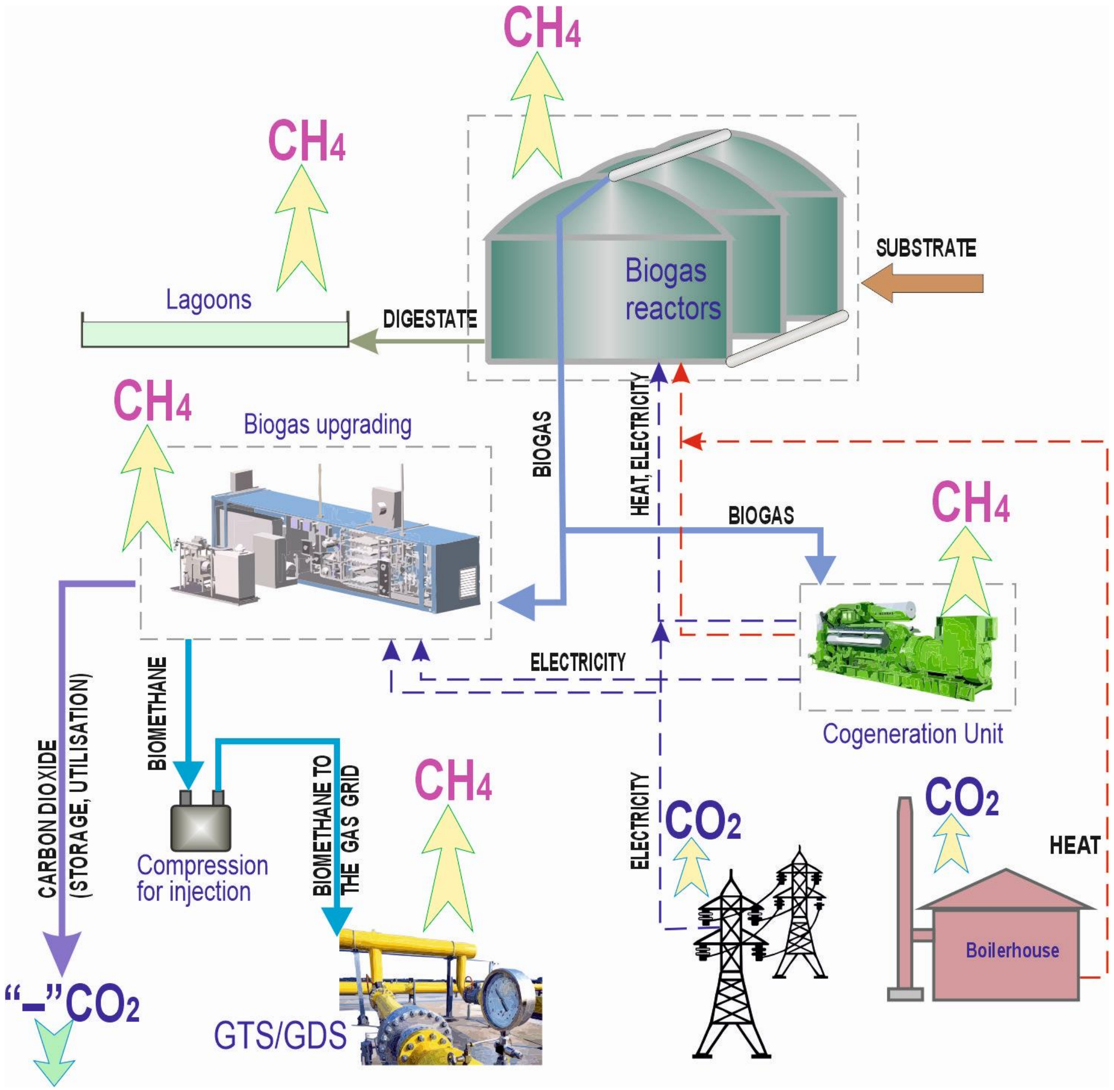
Products vs. Residues – specific GHG emissions

17 times difference ↔





Biogas/biomethane production – what should be taken into account?



1. For e_{sca} a **bonus of 45 g CO_2eq/MJ manure** shall be attributed …in the case animal manure is used as a substrate for the production of biogas and biomethane. It corresponds to "-109.1" g CO_2eq/MJ of biomethane.
2. Diffuse methane emissions from the bioreactor, **1% CH_4** to that formed during fermentation*
3. Methane emissions from open digestate storage sites, g CO_2eq/MJ biogas
4. Methane emissions from the operation of the cogeneration plant, **approx. 1.8%** of the biomethane used by the CHP
5. Methane losses during purification and upgrading, % of the initial content (depends on the upgrading technology)
6. Emissions from wastewater treatment, kg CO_2eq/MJ(biogas), if available.
7. Methane losses during liquefaction, **0.13 kJ/MJ bio-LNG**, if available
8. Methane losses during transportation through the gas network, 0.17 g CH_4/MJ(biomethane)
9. Use of transport fuel by cars and special equipment, corresponding GHG emissions
10. GHG emissions from electricity use for all technological processes
11. GHG emissions from the use of heat from fuel combustion for all technological processes
12. Possible carbon dioxide capture and **Storage or Replacement** (e_{ccs}/e_{ccr})

Calculation options for comparing GHG emissions of biomethane production

- We analysing the joint fermentation of various types of raw materials: **cereal straw** (wheat, rye), **soybean straw**, **corn stalks**, **rapeseed straw**, **oil production waste** (fuz), **pig manure**, and also, for the option of using a CHP, we envisage the use of **corn silage**.
- To maintain the required temperature in the biogas reactor, we consider the following options: a **natural gas boiler** (NG), **agrobiomass boiler** (BM), **biogas cogeneration plant** (CHP), **biogas boiler** (BG), utilization of part of the waste heat energy from the biogas upgrading plant.
- For the supply of electricity for production needs, we consider the following options: electricity from the **network (Grid)**, or from the **CHP**.
- We also considered three common biogas upgrading technologies: **membrane separation** (MS), **chemical absorption** (CA) and **pressure swing adsorption** (PSA) with and without thermal oxidation of methane from waste gases.
- **Biomethane production - 6 million m³/a**

OPTIONS	1	2	3	4	5	6	7	8	9	10
Source of heat	**NG**	NG	NG	BM	BM	BG	CHP	CHP	CHP	CHP
Source of electricity	**Grid**	Grid	Grid	Grid	Grid	Grid	CHP	CHP	CHP	CHP
Methane emissions during biogas production	**+**	+	+	+	+	+	+	+	+	+
Methane emissions during CHP operation	**–**	–	–	–	–	–	+	+	+	+
Methane emissions from open digestate storage sites	**+**	+	+	+	+	+	+	–	–	–
Methane emissions during biogas upgrading	**1.8%**	0.7%	0.1%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%
Biogas upgrading system	**PSA**	MS	CA	MS	MS	MS	MS	MS	MS	MS
CH4 content in BM, %	**97.5**	97.0	98.5	97.0	97.0	97.0	97.0	97.0	97.0	97.0
Specific EE consumption of the biogas upgrading system, kWh/nm3 of biogas	**0.25**	0.29	0.1	0.29	0.29	0.29	0.29	0.29	0.29	0.29
Specific heat consumption of the biogas upgrading system, kWh/nm3 of biogas	**0**	0	0.55	0	0	0	0	0	0	0
BM pressure after the biogas upgrading system, MPa (abs.)	**0.4**	1.4	0.1	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Heat recovery from the biogas upgrading system	**–**	–	–	–	+	+	+	+	+	+
Methane oxidation in exhaust gases	**–**	–	–	–	–	–	–	–	+	+
Further purification and liquefaction of CO2	**–**	–	–	–	–	–	–	–	–	+
Taking into account CO2 capture and replacement	**–**	–	–	–	–	–	–	–	–	+

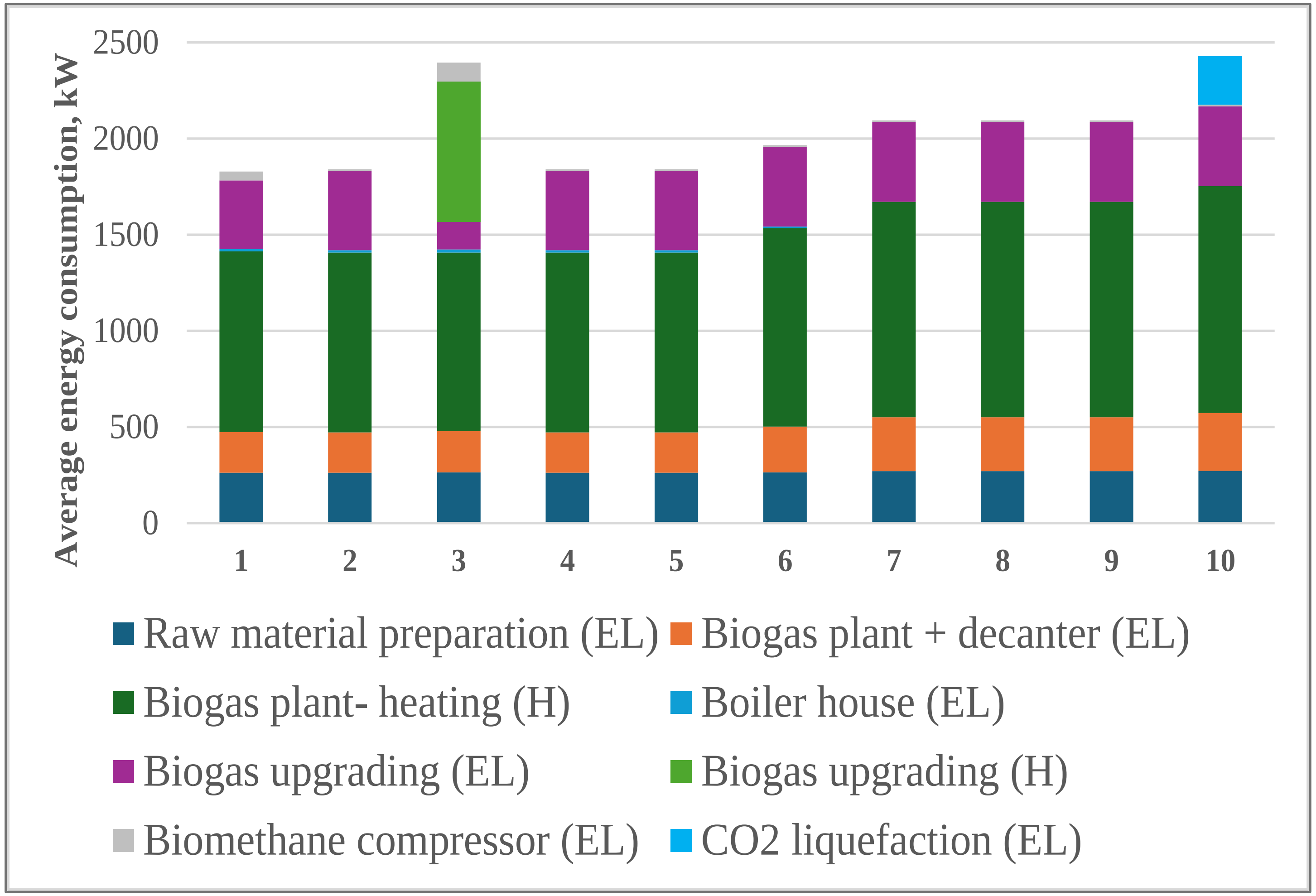
Calculation of GHG emissions from biomethane production under Option 1, g CO_2eq/MJ

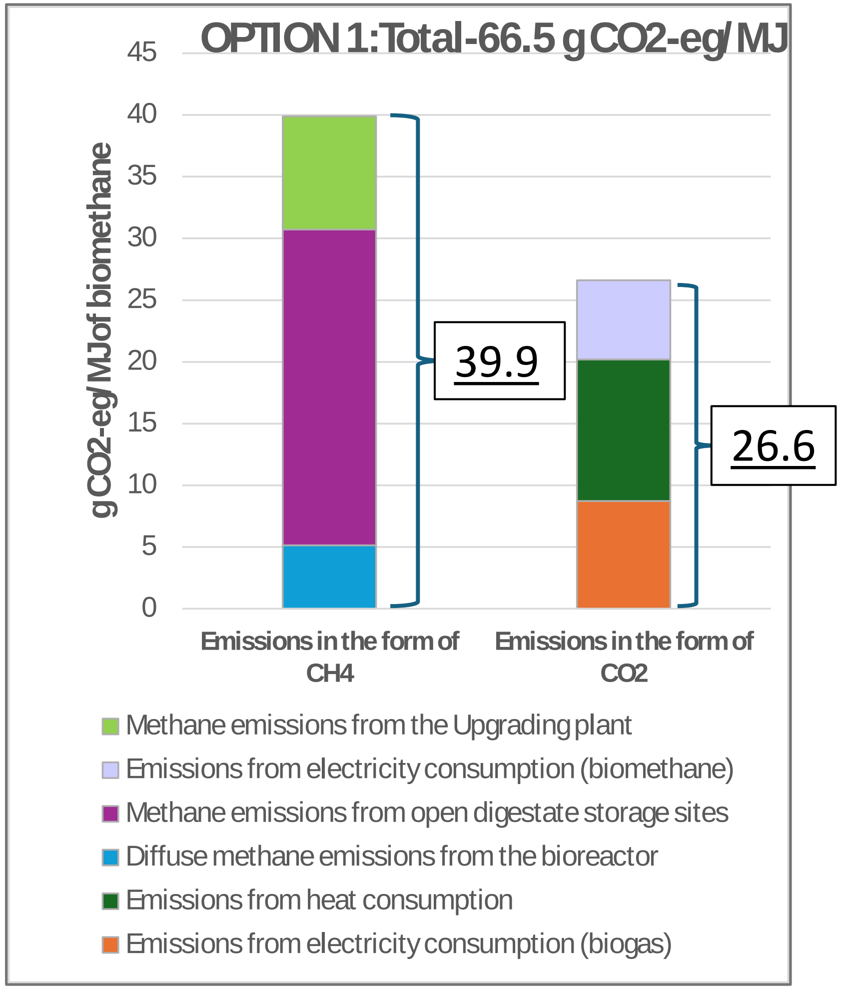
Raw material:	Wheat straw	Rye straw	Rapeseed straw	Corn stalks	Soybean straw	Fus (from oil prod.)	Wet manure	Maize silage
Emissions from extraction and cultivation [$e_{ec,n}+e_{td,n}+e_{l,n}-e_{sca,n}$]	3.9	3.9	3.9	4.1	3.7	4.1	0.0	18.1
Manure credits/Manure credits	0.0	0.0	0.0	0.0	0.0	0.0	-109.1	0.0
Application of the bonus e_B (restoration of degraded land), g CO2eq/MJ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Emissions from production (e_P)	66.5	66.5	66.5	66.5	66.5	66.5	66.5	66.5
Emissions from transportation and distribution of the finished product ($e_{td, product}$)	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Emissions from end use (e_u),	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Emission reduction from CO2 substitution or storage ($e_{ccs/ccr}$)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total emissions (E) for the entire final product (BIOMETHANE)	75.8	75.8	75.8	76.0	75.7	76.0	-37.2	90.0

Weighted average = 72.23 >32.9 g CO_2eq/MJ

Estimated energy consumption for different biomethane production options (biogas/biomethane plant)

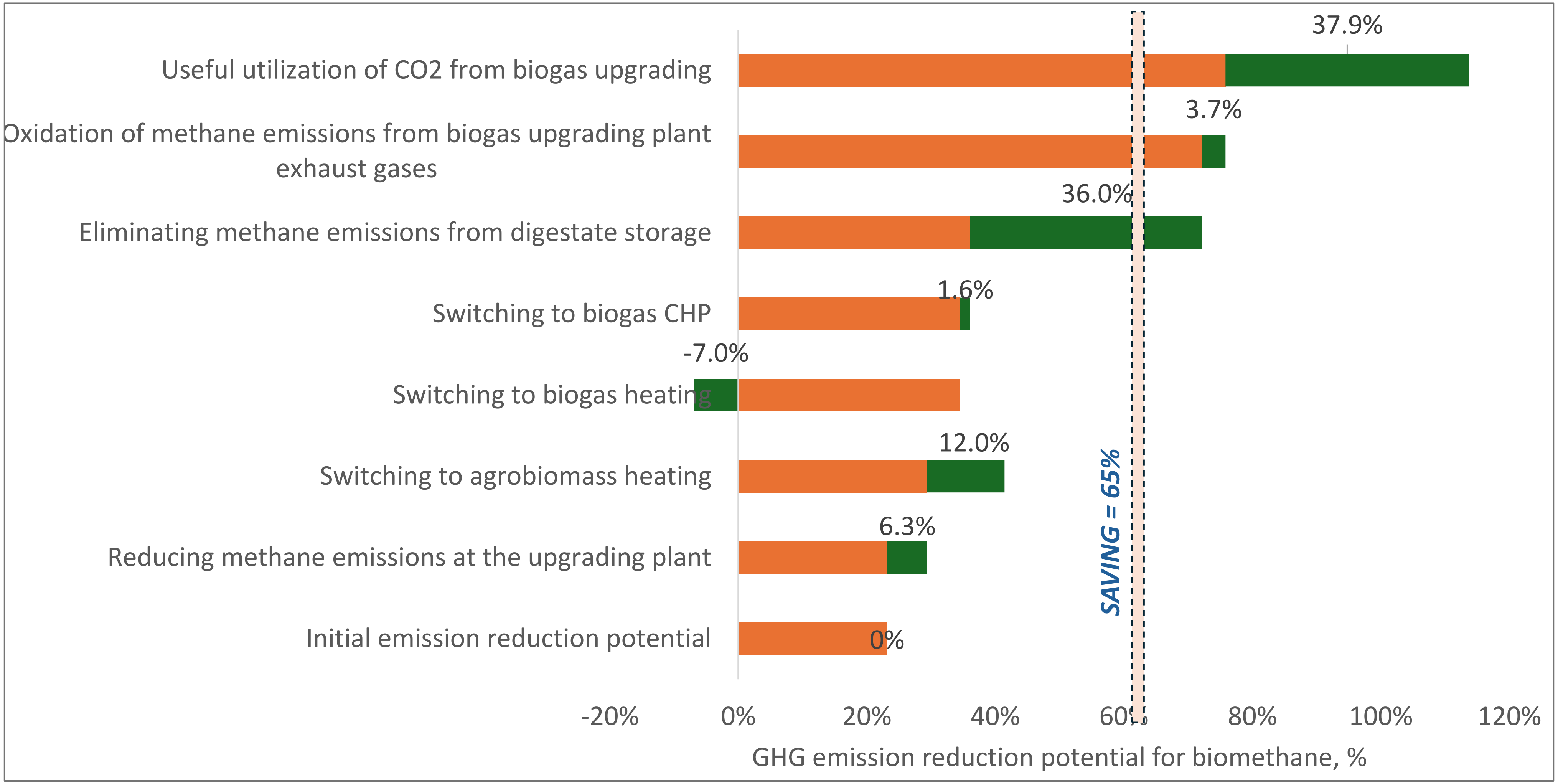
Biomethane production- 6 million m³/a





Change in greenhouse gas emission reduction potential for different measures in biomethane production

(weighted average for biomethane obtained from abovementioned substrates)



Conclusions on the effectiveness of the considered measures

The most effective measures are:

- ***eliminating methane emissions from open storage sites of digestate*** and
- ***replacing carbon dioxide produced by burning fossil fuels with carbon dioxide separated from biogas during the upgrading***

In the considered production model, for all types of raw materials, except manure, it is extremely difficult or even impossible to achieve the desired GHG reduction level for biomethane of 65% without implementing at least one of abovementioned measures.

Measures of medium efficiency are:

- the transition to heating the biogas plant with biomass instead of fossil fuels and
- reducing methane emissions during biogas upgrading by choosing the appropriate technology and equipment.

The least effective measure is the oxidation of methane in the exhaust gases of the biogas upgrading plant.

The transition to CHP to meet energy needs is effective in replacing the use of fossil fuels for heating the boiogas plant. The measure is not effective when replacing agricultural biomass, and it is also limitedly effective when replacing a boiler house that used to run on biogas.

Final remarks

It should be noted that other ways to increase the GHG in biomethane production, not considered in this analysis, may be the following:

- increasing the proportion of manure in the raw material mixture, but taking into account the possible increase in GHG emissions from open storage sites of digestate;
- ensuring the most complete decomposition of bioavailable organic matter within sealed bioreactors, which guarantees the minimization of residual methane release during subsequent open storage of digestate;
- in-depth processing of digestate, which guarantees its stabilization and avoidance of GHG emissions;
- implementation of a set of measures to avoid or minimize methane leaks from the biogas production station and an appropriate monitoring system to confirm the effectiveness of such measures;
- application of the **e_B bonus** (for the restoration of degraded lands) in the amount of **29 g CO_2eq/MJ biomass fuel**, if there is relevant evidence;
- application of the **e_{sca} bonus** (for improved agricultural management), if there is relevant evidence. The maximum possible total value or annual requirement for **e_{sca}** is **25 g CO_2eq/MJ** biofuel per year for the entire period of application of the e_{sca} practice. If biochar is used as an organic soil improver alone or in combination with other eligible e_{sca} methods, the maximum possible value for the annual application increases to **45 g CO_2eq/MJ biofuel** *(ISCC EU 205 Greenhouse Gas Emissions. Version 4.2. Valid from: 21 May 2025)*.

Thank you for your attention!

UABIO

Bioenergy Association of Ukraine

uabio.org

Volodymyr Kramar, Ph.D.,
expert of the Bioenergy Association of Ukraine,
kramar@secbiomass.com