Conference: Biomethane in Ukraine: Opportunities and Development
Kyiv, June 10, 2025

Results of Analytical Note No. 2 “Advanced biomethane production from ligno-cellulose materials”

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Key definitions

Directive (EU) 2018/2001 (RED III) provide the following means for **ligno-cellulosic materials**:

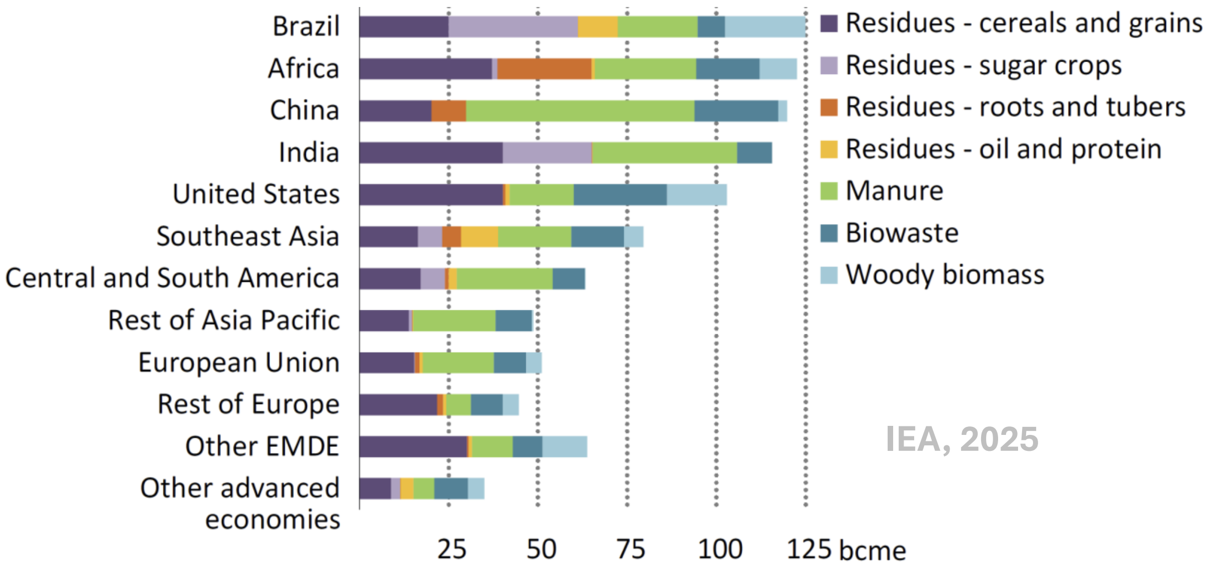
‘ligno-cellulosic material’ means material composed of lignin, cellulose and hemicellulose, such as biomass sourced from forests, woody energy crops and forest-based industries' residues and wastes;

‘non-food cellulosic material’ means feedstock mainly composed of cellulose and hemicellulose, and having a lower lignin content than ligno-cellulosic material, including **food and feed crop residues, such as straw (Annex IX part A), stover (Annex IX part A)**, husks and shells; grassy energy crops with a low starch content, such as ryegrass, switchgrass, miscanthus, giant cane; cover crops before and after main crops; ley crops; industrial residues, including from food and feed crops after vegetal oils, sugars, starches and protein have been extracted; and material from biowaste, where ley and cover crops are understood to be temporary, short-term sown pastures comprising grass-legume mixture with a low starch content to obtain fodder for livestock and improve soil fertility for obtaining higher yields of arable main crops.

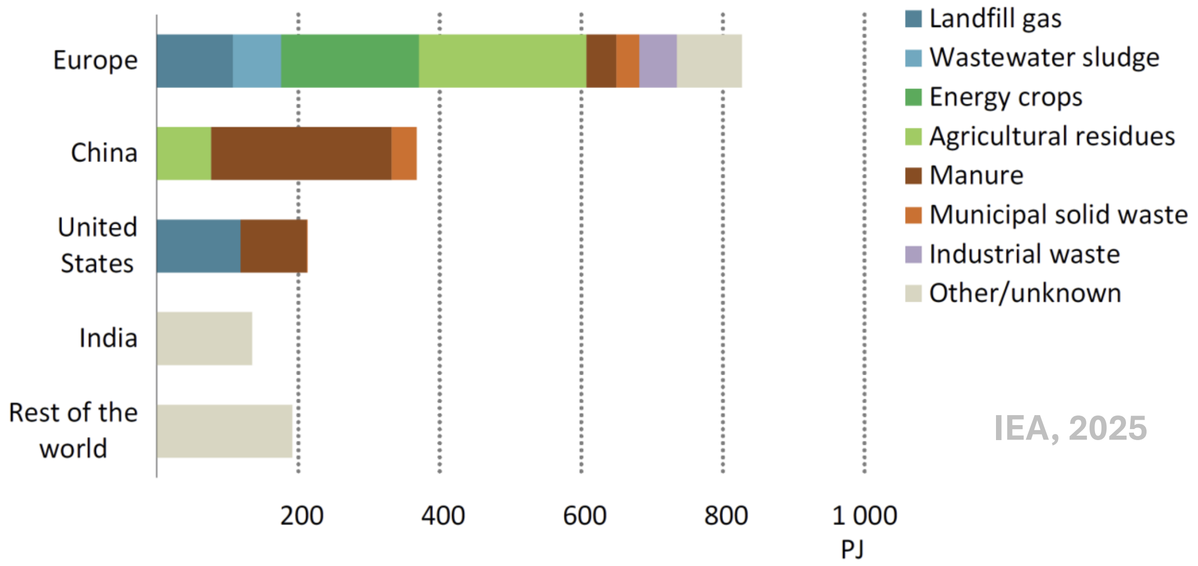
Crop residues means the leftovers from the harvest, essentially the plant parts that aren’t used for food or other direct human consumption. Common examples include straw from wheat or rice, corn stalks, soybean stems, and other plant debris left in the field after harvesting.

Current status and prospects of using crop residues for biomethane production

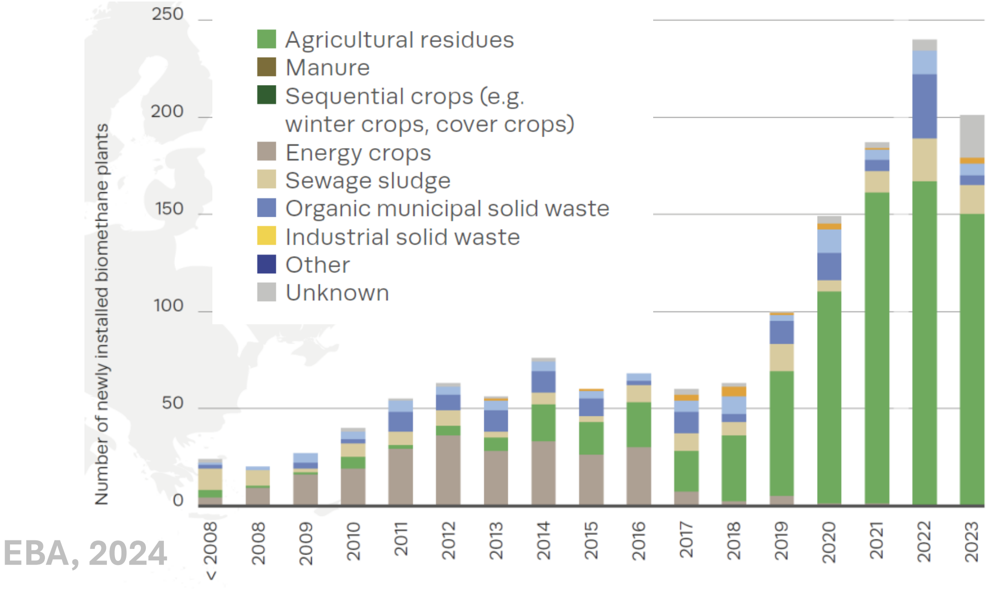
Potential for biogases by region and by feedstock type, 2024



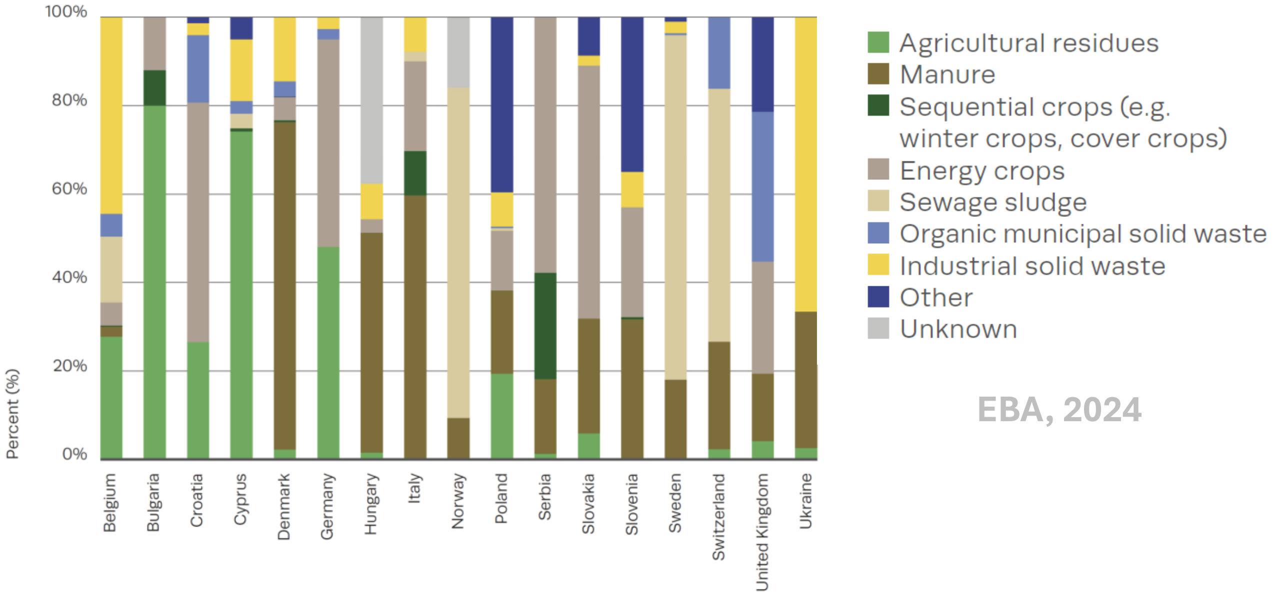
Feedstock use for production of biogases by selected region, 2023



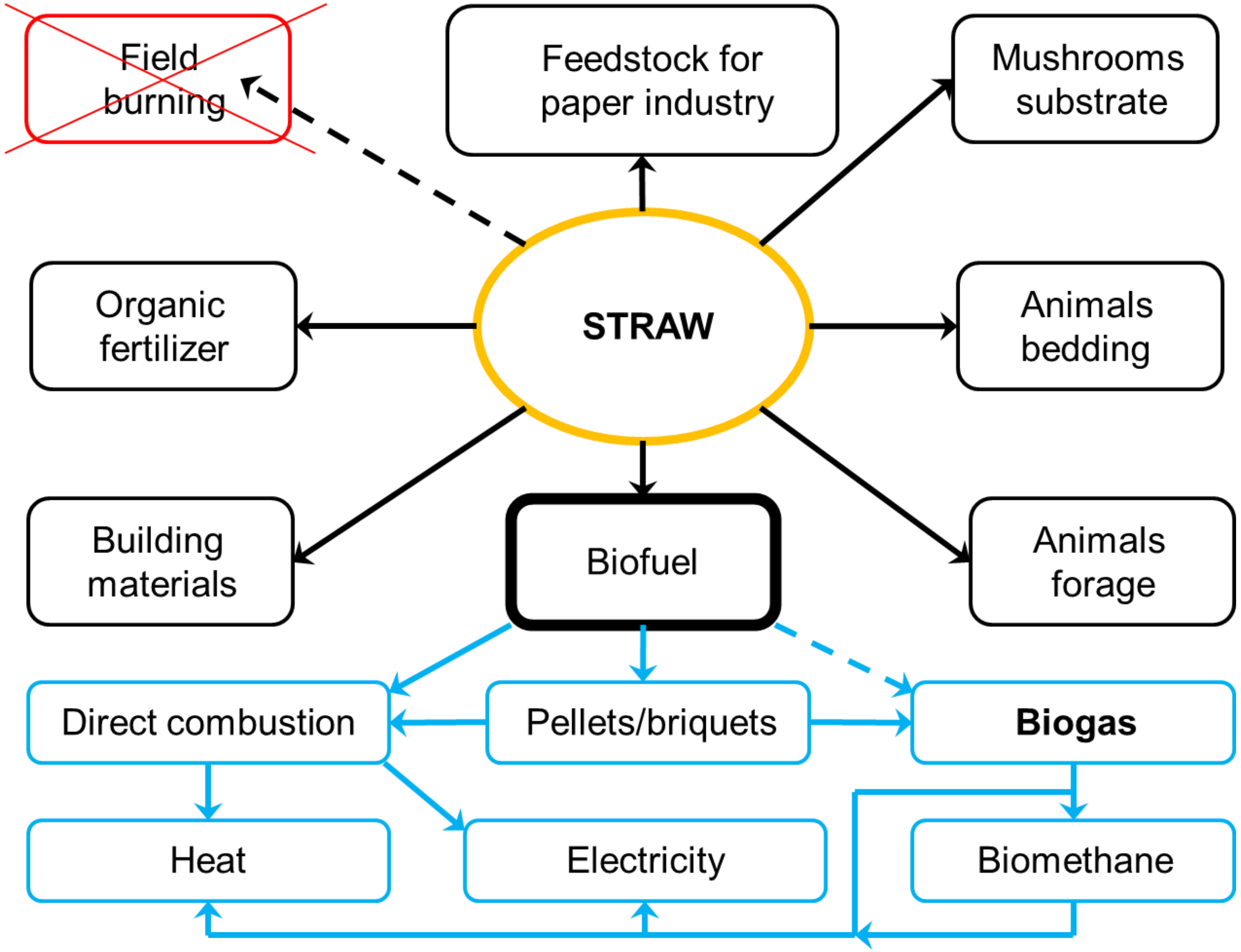
New biomethane plants in Europe by feedstock, 2008-2023



Shares of feedstock use in selected European countries, 2023



The main types of crop residues in Ukraine

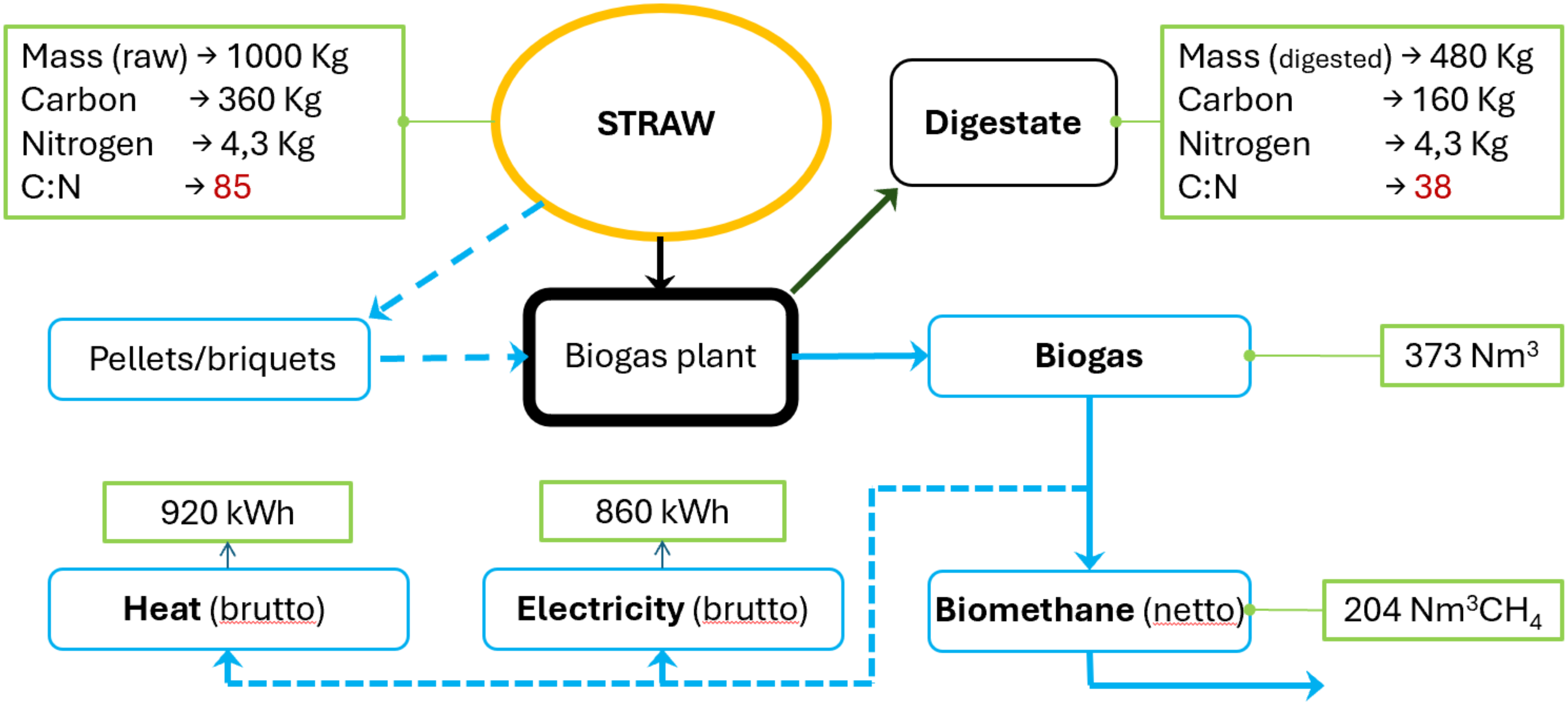


Crop	Residue type
Wheat	Straw (stalks and leaves)
Barley	Straw (stalks and leaves)
Corn	Stover (stalks, leaves, husks, and cobs)
Sunflower	Stover, heads
Rapeseed	Straw (stems, leaves)
Soybean	Straw (stems, leaves)

Wheat straw

Corn stower

An example of material and energy balance for biogas production from wheat straw



The main properties of crop residues as feedstock for biogas production

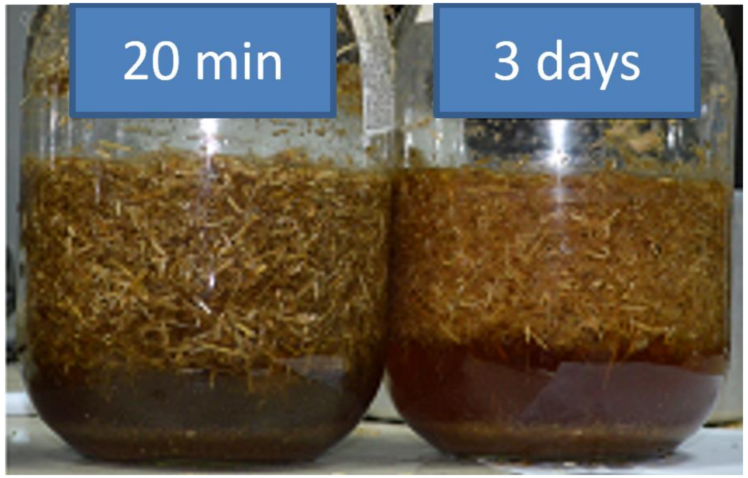
Crop Residue	TS (%)	C:N	CEL	HCEL	LGN	Hydrophobicity Level	Key Hydrophobic Factors
Wheat straw	84-92	60-100	32-42	20-28	15-21	High	High lignin, waxy cuticle, silica
Corn stalks	72-84	45-65	34-45	22-30	12-18	Moderate–High	Moderate lignin, less waxy
Sunflower stalks	76-85 (after field curing)	40-60	30-42	20-28	15-22	Moderate–High	Waxy surface, rigid
Rapeseed straw	80-90	50-75	30-40	18-26	18-24	Moderate	Moderate lignin, thinner wax
Soybean straw	82-88	25-35	32-42	20-26	14-20	Low–Moderate	Lower lignin, porous

Key factors affecting AD

- **low moisture content**
- **high (non-optimal) C:N ratio**
- **hydrophobicity**
- **high lignin content and low bioavailability**

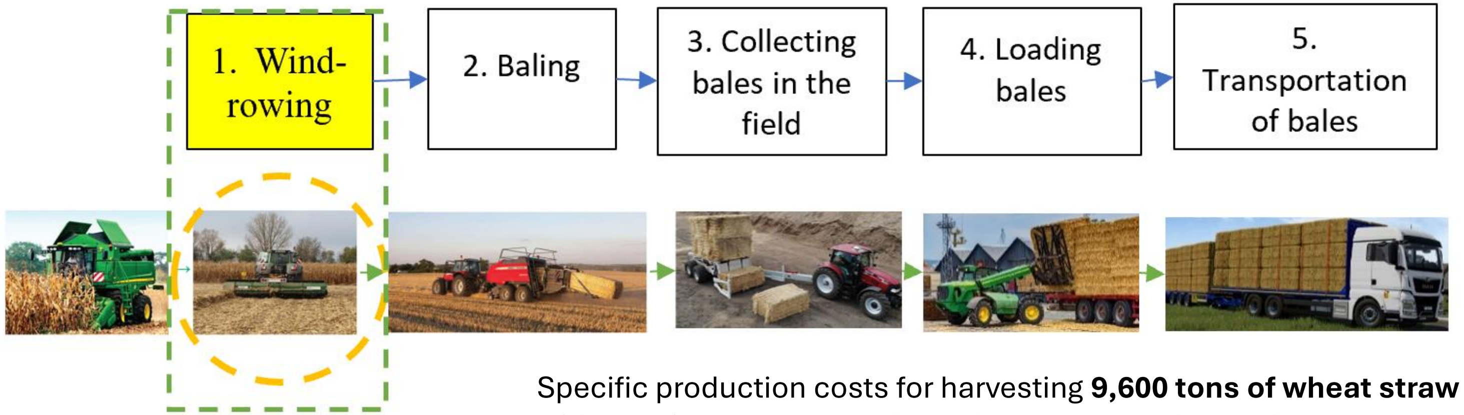
Cuticle based hydrophobicity

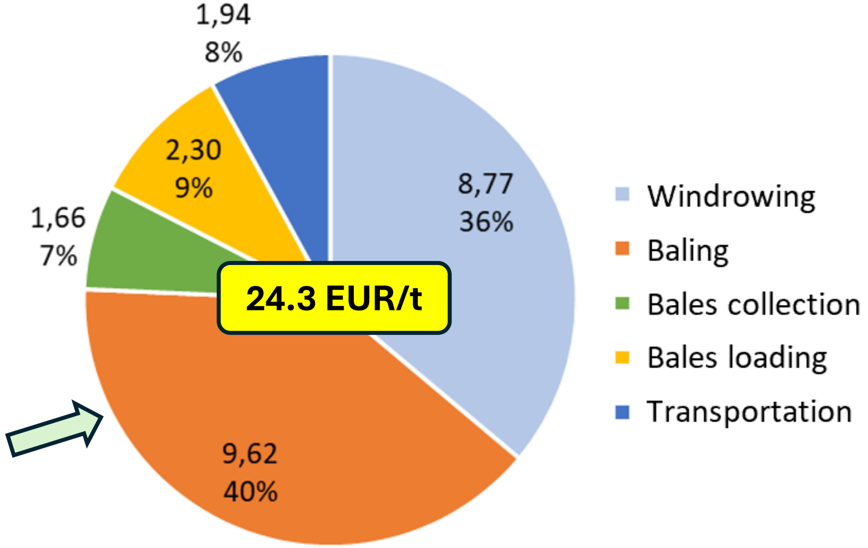
Water soaking test



Technological schemes and production cost of baled straw and baled corn stover

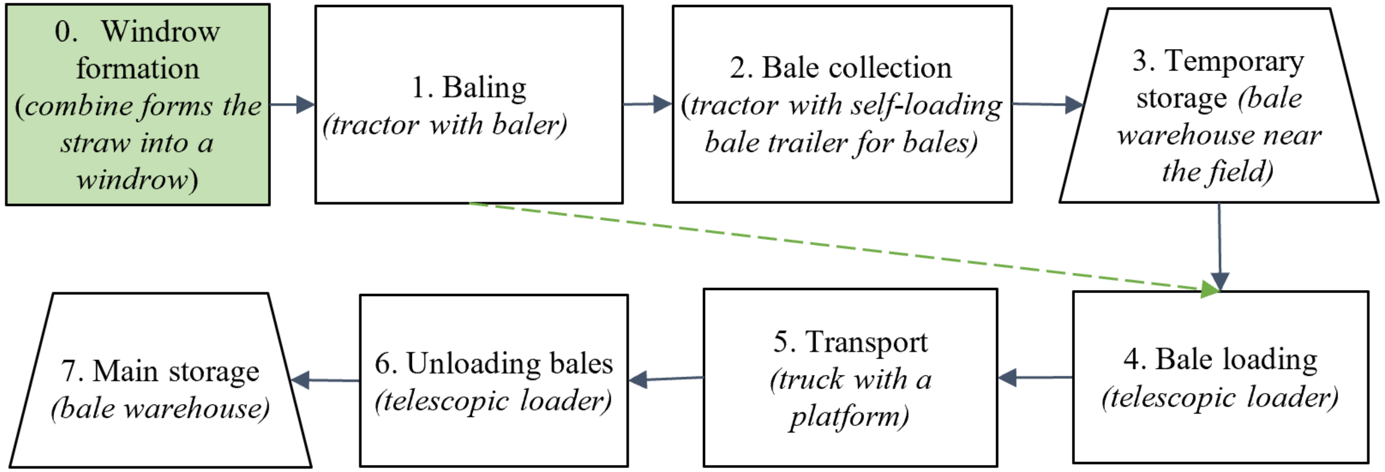
Corn stover

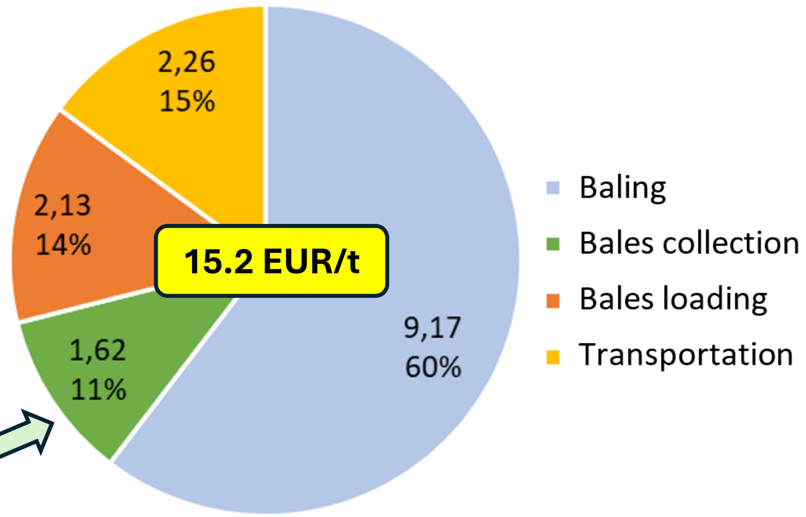




Specific production costs for harvesting **9,600 tons of wheat straw** with a moisture content of 15% from an area of **2,400 hectares**

Straw





Specific production costs for harvesting **8,550 tons of corn stover** with a moisture content of 25% from an area of **1,900 hectares**

Straw pretreatment methods and effects

Physical	Chemical	Biological	Combined processes
▪ Mechanical ▪ Thermal ▪ Ultrasound ▪ Electrochemical	▪ Alcali ▪ Acid ▪ Oxidative	▪ Microbiological ▪ Enzymatic	▪ Steam explosion ▪ Extrusion ▪ Thermochemical

Process	Cellulose decrystali-sation	HCEL degradation	Lignin degradation	Increasing specific surface
Biological				+
Milling	+			+
Steam explosion		+	+	+
Concentrated acid		+	+	+
Diluted acid		+		+
Alcali		-	+	+
Extrusion				+

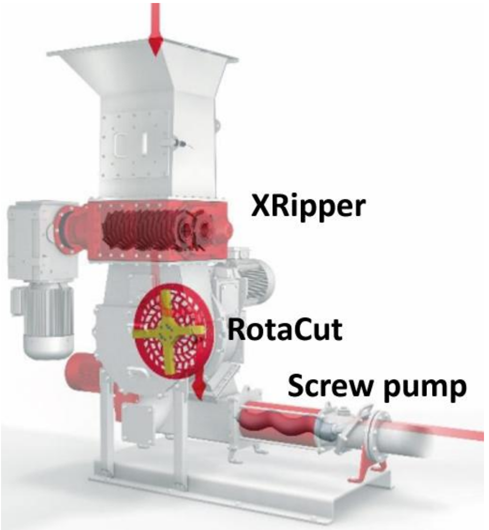
A plus symbol (+) indicates that the pretreatment method has this effect, a minus symbol (-) indicates that it has no effect, and no symbol means it is unclear if there is an effect or not.

Process	Advantages	Disadvantages
Milling	• increases surface area • makes substrate easier to handle • often improves fluidity in digester	• increased energy demand • high maintenance costs / sensitive to stones etc.
Hot water (TDH)	• increases the enzyme accessibility	• high heat demand • only effective up to certain temperature
Alkali	• breaks down lignin	• high alkali concentration in digester • high cost of chemical
Microbial	• low energy consumption	• slow • no lignin breakdown
Enzymatic	• low energy consumption	• continuous addition required • high cost of enzymes
Steam explosion	• breaks down lignin and solubilises hemicellulose	• high heat and electricity demand • only effective up to certain temperature
Extrusion	• increases surface area	• increased energy demand • high maintenance costs / sensitive to stones etc.
Acid	• solubilises hemicellulose	• high cost of acid • corrosion problems • formation of inhibitors, particularly with heat

Examples of the straw pretreatment equipment

BIOEXTRUDER LEHMANN

VOGELSANG PREMIX



STRAW MILLING PLANT by Euromilling / Lin-Ka

BIOCRUSHER BIO-G

MAXXIMIZER MethaPlanet

BIOGRINDER MEBA

Feasibility study: feedstock and products

Feedstock	Feedstock consumption	BMP CH_4	% CH_4	CH_4 yield
	t/year	Nm^3CH_4/t	%	$Nm^3CH_4/year$
Pig manure (TS 4%)	90 000	12	65%	1 046 520
Wheat straw (TS 85%)	9 312	216	55%	1 908 434
Corn stover (TS 75%)	8 123	186	55%	1 117 292
Maize silage (TS 35%)	15 974	108	55%	1 516 718
TOTAL	**141 614**	**-**	**57%**	**5 915 203**

Product	Unit	Output per concept:		
		Concept 1 – Biomethane from straw (extruded) + liquefied CO_2	**Concept 2** – Biomethane from pellets + liquefied CO_2	**Concept 3** – Biomethane from straw (extruded) only
Biomethane (98% CH_4)	thousand Nm^3/year	4 455.3	4 756.9	4 455.3
	MWh/year	43 540	46 488	43 540
Liquefied CO_2 (99.99%)	%	5 561	6 001	0
Digestate, incl.:	t/year	109 760	110 928	107 344

Feasibility study: CAPEX & OPEX

CAPEX component	Cost, thousand euros, including VAT and customs duties		
	Concept 1 – Biomethane from straw (extruded) + liquefied CO_2	Concept 2 – Biomethane from pellets + liquefied CO_2	Concept 3 – Biomethane from straw (extruded) only
TOTAL	**13 928.2**	**13 908.5**	**11 950.0**
Biogas production complex	6 060.0	5 710.5	5 981.1
Equipment and technology for pre-processing straw and corn stover	736.2	800.5	736.2
Machinery and technology for ensiling and transporting silage to the biogas plant	175.5	175.5	175.5
Silo storage	383.4	513.0	305.9
Biogas CHP	956.6	1 114.4	859.0
Backup boiler room	248.4	268.9	215.3
Biogas upgrading complex to biomethane	2 310.0	2 173.0	2 310.0
CO_2 liquefaction complex	1 485.5	1 485.5	-
Biomethane transfer unit to the gas transmission system (main + backup compressor, 5 km gas pipeline, gas metering unit, chromatograph)	1 137.4	1 169.5	1 137.4
Machinery and technology for CO_2 logistics	195.1	195.1	-
Connection to the power grid	58.4	120.9	47.8
Machinery and technology for digestate operations	61.7	61.7	61.7
Design	120.0	120.0	120.0

OPEX component	Cost, thousand euros, excluding VAT		
	Concept 1 – Biomethane from straw (extruded) + liquefied CO_2	Concept 2 – Biomethane from pellets + liquefied CO_2	Concept 3 – Biomethane from straw (extruded) only
TOTAL	2 082.2	2 388.3	1 886.0
Raw materials	873.9	873.9	806.3
Raw materials logistics	99.2	72.4	89.0
Biogas production	70.6	67.0	70.6
Pre-treatment of straw and corn stalks	85.0	270.2	85.0
Combined production of electricity and heat in biogas CHP	47.8	46.4	47.8
Maintenance of a backup boiler room	9.3	10.0	13.2
Enrichment of biogas to biomethane	109.9	103.4	109.9
Liquefaction of CO_2	30.9	30.9	-
Liquefaction of CO_2 logistics	89.0	96.0	-
Biomethane logistics	242.6	277.8	242.6
Digestate operations	61.7	62.0	59.2

Feasibility study: the key project KPIs

Index	Unit	Value		
		Concept 1 – Biomethane from straw (extruded) + liquefied CO_2	**Concept 2 –** Biomethane from pellets + liquefied CO_2	**Concept 3 –** Biomethane from straw (extruded) only
Investments (CAPEX), including:	million euros	13,93	13,87	11,95
Borrowed funds	million euros	8,36	8,32	7,17
Own funds	million euros	5,57	5,55	4,78
Operating expenses (OPEX), including:	million euros/year (excl. VAT)	1,98	2,24	1,89
Raw materials	million euros/year (excl. VAT)	0,97	0,95	0,90
Operating expenses	million euros/year (excl. VAT)	0,35	0,53	0,33
Logistics of target products	million euros/year (excl. VAT)	0,39	0,42	0,30
Revenue	million euros/year (excl. VAT)	4,87	5,15	3,73
Biomethane in GTS	million euros/year (excl. VAT)	3,96	4,18	3,57
Liquefied CO_2	million euros/year (excl. VAT)	0,74	0,80	-
Digestate	million euros/year (excl. VAT)	0,16	0,17	0,16
NPV	million euros	6,07	6,25	1,23
IRR	%	**20,6%**	**20,9%**	**12,5%**
PI	-	0,44	0,45	0,10
Simple payback period	years	5,8	5,7	7,8
Discounted payback period	years	**7,6**	**7,5**	**12,1**

Feasibility study: the key project KPIs

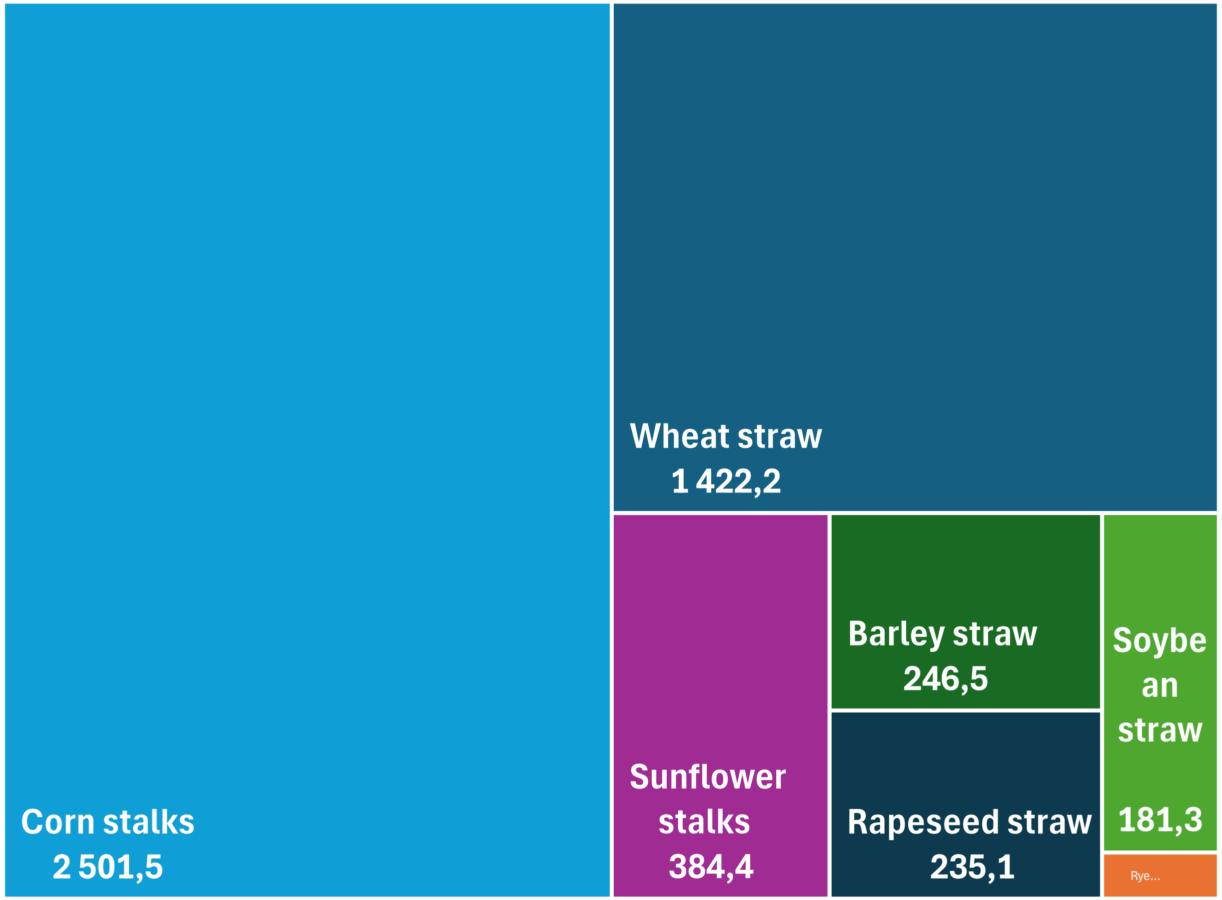
Index	Unit	Value		
		Concept 1 – Biomethane from straw (extruded) + liquefied CO_2	**Concept 2 –** Biomethane from pellets + liquefied CO_2	**Concept 3 –** Biomethane from straw (extruded) only
Project capacity	$MW_{biomethane}$	4.97	5.31	4.97
Specific CAPEX	ths. EUR/$MW_{biomethane}$	2 802	2 614	2 404
Specific OPEX	EUR/$MWh_{biomethane}$	45.5	48.1	43.3
LCOE for 15 years	EUR/$MWh_{biomethane}$	53.8	55.8	50.4
Total electricity consumption	MWh/year	7 482	9 973	5 981
Specific electricity consumption	kWh/$MWh_{biomethane}$	171.8	214.5	137.4
Carbon intensity of biomethane	$gCO_{2-eq}/MJ_{biomethane}$	**-17.33**	**-14.05**	**14.94**

Examples for biomethane production from crop residues

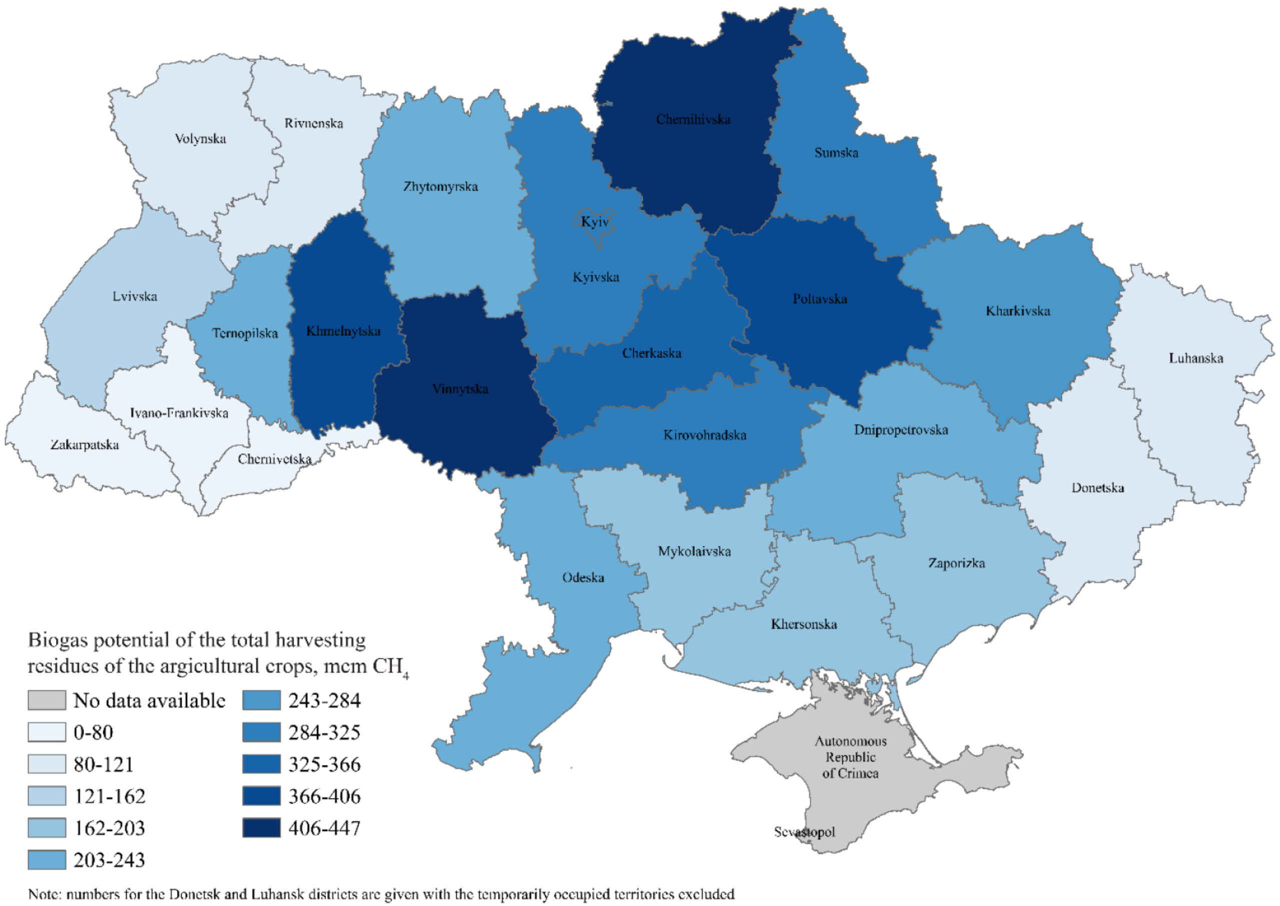
Facility/ project name	Feedstock treated in ton/a	Feedstock type	Feedstock (pre)-treatment	CH_4 production, mcm	Project start up	Cost, mill EUR (M€)	Country
Chernozemen	50,000	Cow manure, maize silage, straw	Hammer mill	3.8*	n.a.	n.a.	Bulgaria
Foulum	17,000 (8.5% straw)	Straw, pig manure	Briquetting	>1.7 (biogas)	2012	n.a.	Denmark
VERBIO	40,000	Straw	Mechanical grinding	14	2014	25	Germany
VERBIO	75,000 - 100,000	Corn stover	Grinding and thermal treatment by hot water	68	2021	115	USA
Fuyu county	30,000	Yellow corn straw	Crushing (less than 3 cm) and ensiling with organic acids	~ 4.6*	2016	55 mill yuan (~ 7 M€)	China
Harbin 1	95,000	Corn and rice straw	Fermentation (hydrolysis) and agitation	29**	2019	n.a.	China
Harbin 2	116,000	Corn and rice straw	Fermentation and agitation	45	2022	43	China
Agri biogenic energy park	196,000	Manure, straw, bedding, grass, potato pulp, leaves	Sauter biogas technology	13	2016	n.a.	Denmark
Kværs	800,000	Manure (?) and straw	Thermal and mechanical grinding of straw	20	2022	n.a.	Denmark
Charpentier	17,000	SBP, cereal residuals and energy crops	Mixing pump including shredding unit	1.6	2021	n.a	France
Alliance Berry	80,000	Manure + wheat residuals	Standard treatment	5.4	2022	22	France

Biomethane production potential from crop residues in Ukraine

Totally – 5.2 billion Nm^3CH_4 per year



From 10 to 447 mln Nm^3CH_4/yr per oblast



Thank you for your attention!

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