Conference

“Biomethane in Ukraine: Opportunities and development”

12.06.2025, Kyiv

Advanced biomethane production from intermediate and cover crops

Results of Analytical Note 1

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Agricultural crops

Main crops are those that occupy the field for most time of the growing season

Intermediate crops are grown in the time interval free from the cultivation of main crops in crop rotations

A mix of post-harvest crops after maize in the USA (Photo by the authors of the Analytical Note)

- ✓ Due to **intermediate (cover) crops**, it is possible to obtain **two harvests** from the same area during a year (12 months), while irrigated lands may give even three harvests.
- ✓ Depending on the biological characteristics and cultivation technology, **intermediate crops** are divided into **post-hay harvest**, **post-harvest**, **winter**, and **under-sown** crops.

https://textbook.com.ua/geografiya/1473445276

Intermediate crops as feedstock in Directive (EU) 2018/2001 (RED III)

- **Intermediate** crops are actually **excluded** from «food and feed crops» (p. 40, Article 2 «Definitions»): 'food and feed crops' means starch-rich crops, sugar crops or oil crops produced on agricultural land as a main crop **excluding** residues, waste or ligno-cellulosic material and **intermediate crops**, such as catch crops and cover crops, provided that the use of such intermediate crops **does not trigger demand for additional land**.

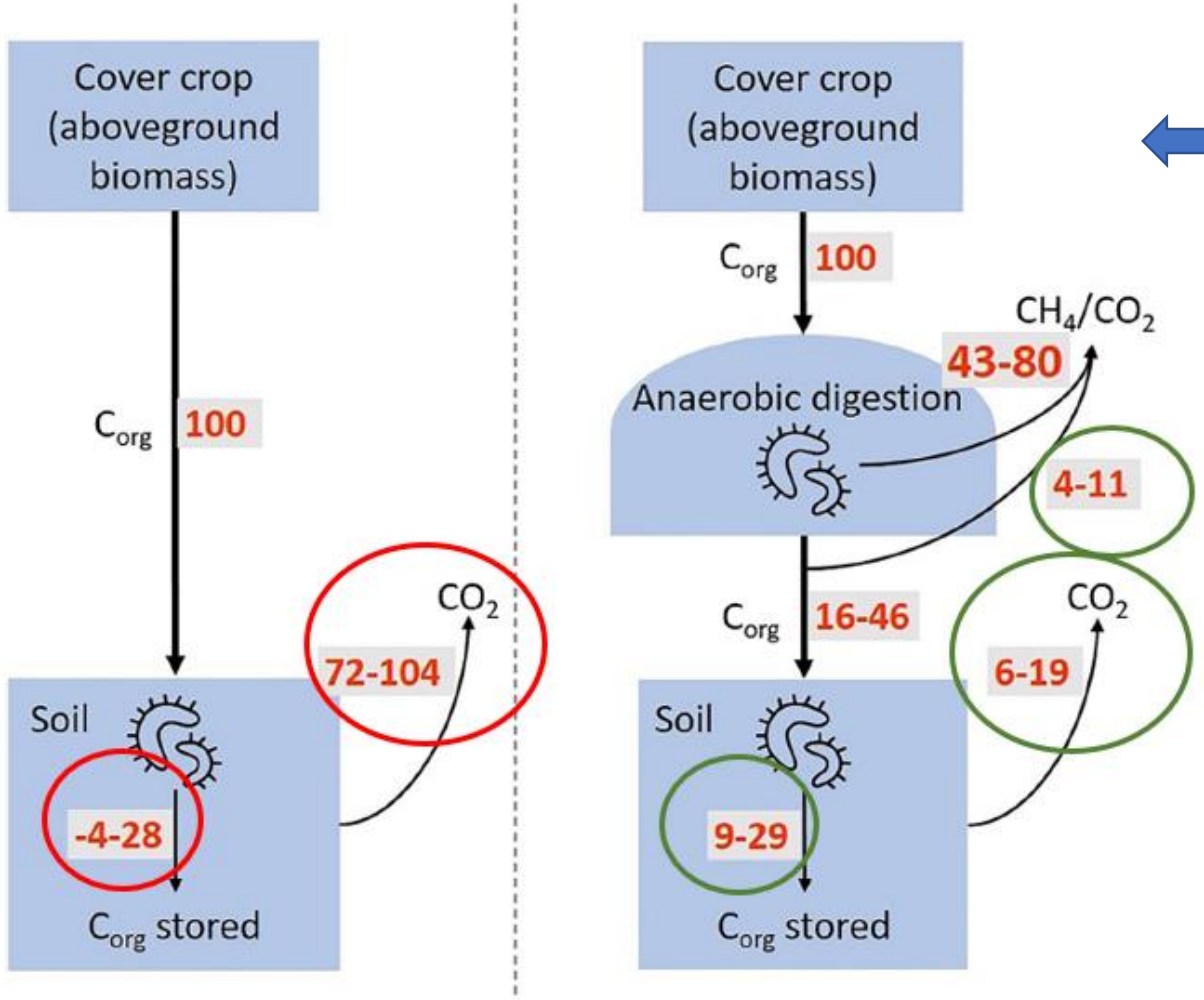
- **RED III**, Annex IX, **Part A** «Feedstocks for the production of biogas for transport and **advanced** biofuels»: **Intermediate crops**, such as catch crops and cover crops that are grown in areas where due to a short vegetation period the production of food and feed crops is limited to one harvest and provided their use does not trigger demand for additional land, and provided the soil organic matter content is maintained, where used for the production of **biofuel for the aviation sector**.

https://swellseedco.com/blogs/news/what-are-cover-crops

- **RED III**, Annex IX, **Part B** «Feedstocks for the production of biofuels and biogas for transport»: **Intermediate crops** are included with the same formulation as in Part A, except for they are **not used** for the production of **biofuel for the aviation sector**».

Directive (EU) 2018/2001 *https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02018L2001-20240716*

Impact on soil from the use of intermediate and cover crops for biomethane production



C_{org} balance: -4…28

C_{org} balance is positive: 9…29

Theoretical study of French experts (2022):
Carbon balance in case of incorporating the aboveground biomass of a cover crop into the soil and in case of returning the cover crop digestate to the field.
https://doi.org/10.1007/s13593-022-00790-8

Field study and modelling of Austrian experts
(Syn-Energy project 2010-2015, 5 cover crop options):

- When harvesting biomass of cover crops with a yield of **2.5 t d.m./ha** and returning the equivalent volume of digestate to the field, the **humus carbon input** to the soil is **112 kg/ha**.
- If the same cover crops are applied to the soil as green manure, the humus carbon input is only **80 kg/ha**.

https://publications.waset.org/10005395/biogas-from-cover-crops-and-field-residues-effects-on-soil-water-climate-and-ecological-footprint

Model BiogasDoneRight™ (Italy)

In Italy, sequential cultivation (harvesting two crops per year) is widespread thanks to the introduction of a new model for **sustainable** food, feed and biogas production – **Biogasdoneright™** . According to the model:

the main crops are grown for food or feed; the intermediate crops can be used for biogas/ biomethane; digestate can be applied as organic fertilizer instead of purchasing additional mineral fertilizers.

Currently, the Biogasdoneright™ model is introduced on more than **600 farms** in Italy and in France;
10 million USD have been invested in pilot studies in the USA.

Example of implementing Biogasdoneright™ on a farm near Ferrara (the Po valley in Northern Italy)

Before:

Land of 320 ha: maize silage for BGP (270 ha) and for feed for cows (30 ha); alfalfa for feed for cows (20 ha)

Purchasing maize silage for BGP (equivalent of 70 ha)

Biogas plant (BGP) of 1 MW_{el}

BiogasDoneRight

After:

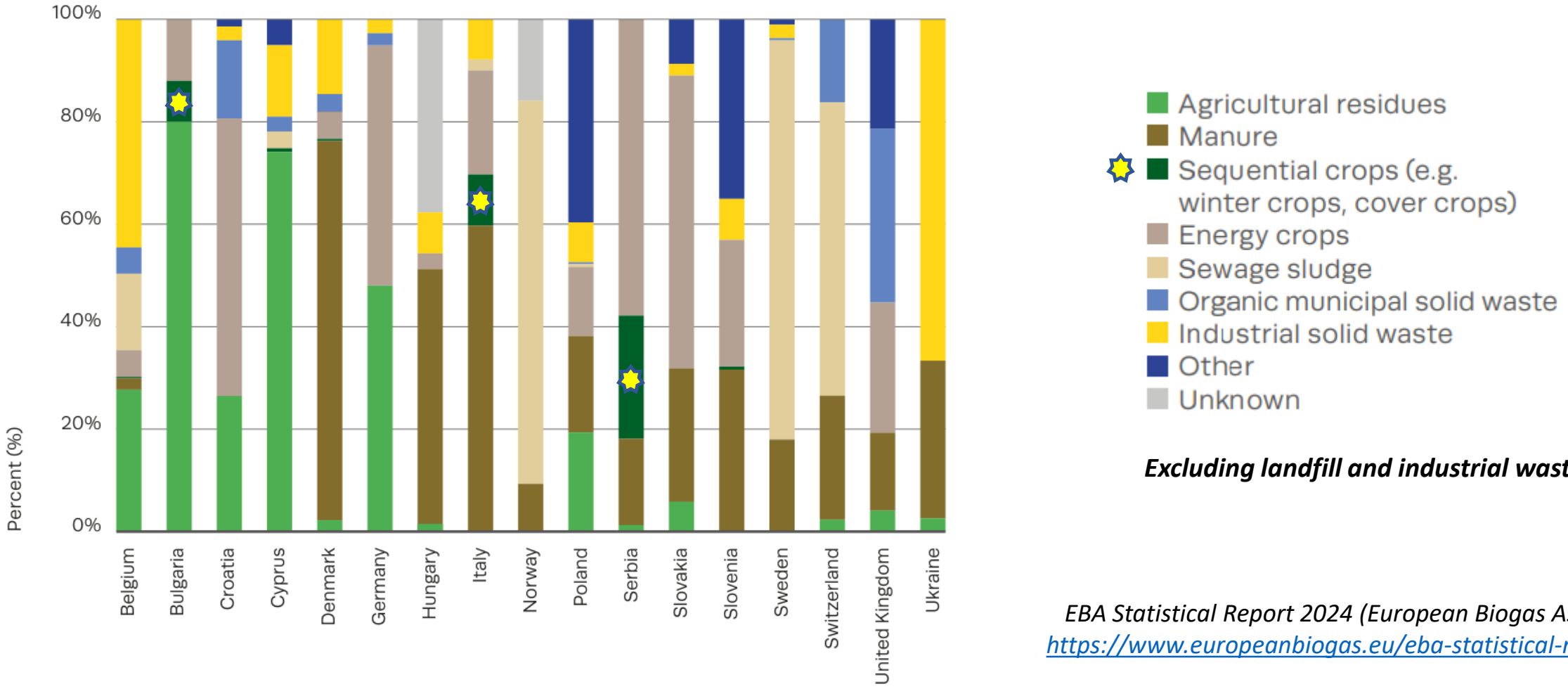
Land of 320 ha: plots of 110, 100*, 60, 30 ha with growing main and intermediate crops; 20 ha with alfalfa for feed for cows. **The only exemption from the model: sorghum silage as a main crop on 10 ha is for biogas.*

Complete provision of BGP with **own feedstock**

Digestate is returned to the field. **No need** to purchase mineral fertilizers.

https://www.consorziobiogas.it/wp-content/uploads/2017/05/Biogasdoneright-No-VEC-Web.pdf

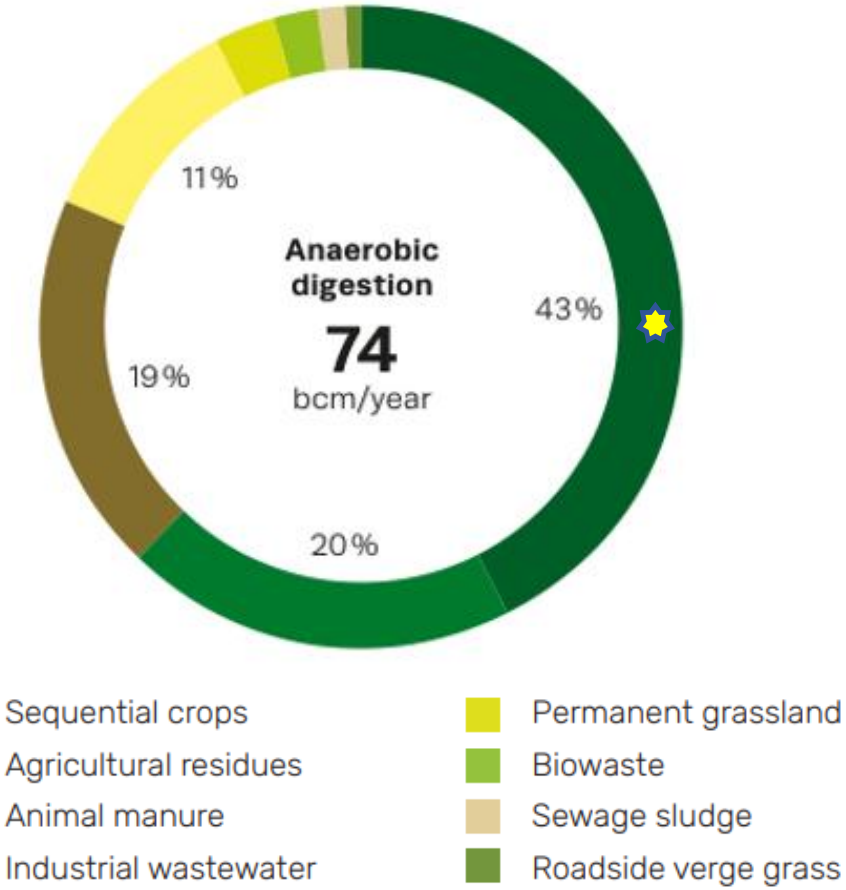
Structure of feedstocks used for biogas production in selected European countries (2023)

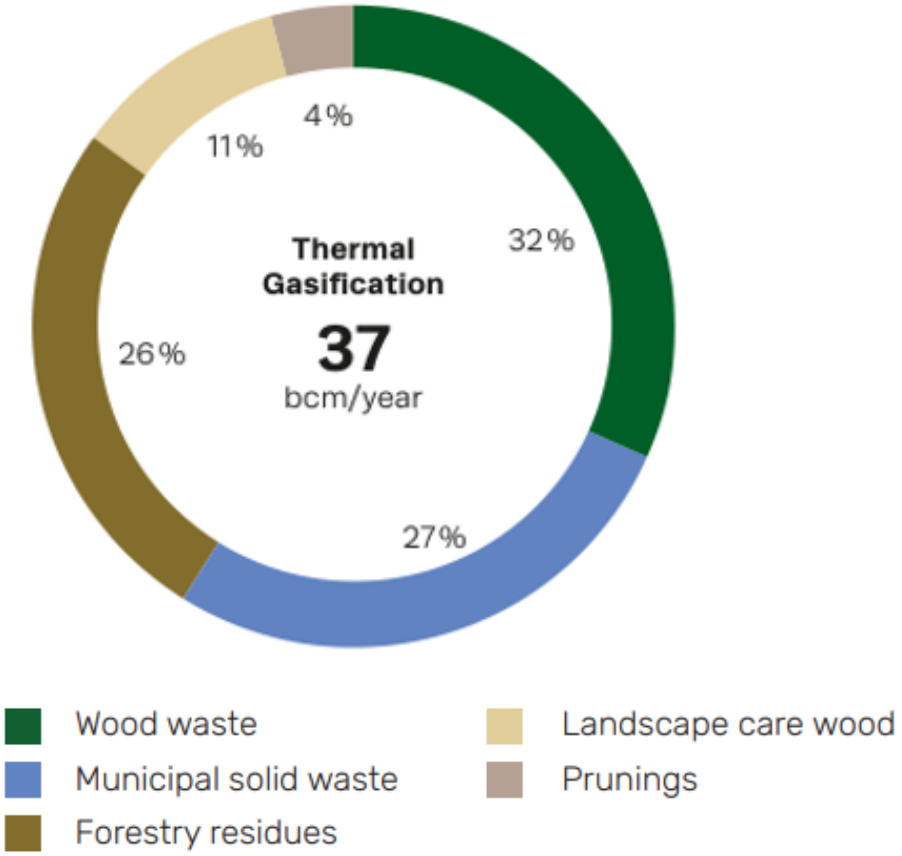


Excluding landfill and industrial wastewater

EBA Statistical Report 2024 (European Biogas Association)
https://www.europeanbiogas.eu/eba-statistical-report-2024/

Potential and feedstock structure for biomethane production in Europe in 2040

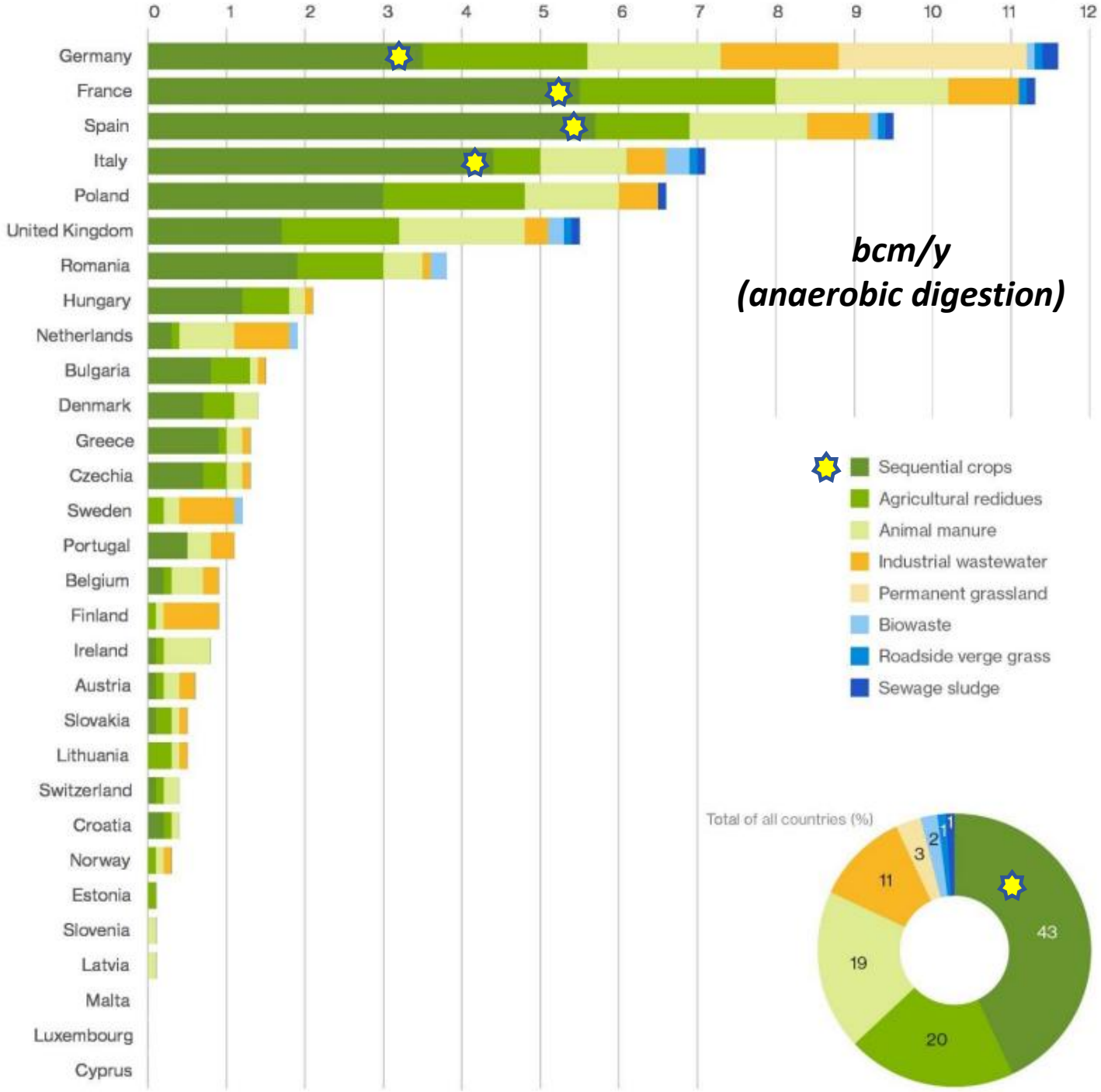




Europe (the EU), bcm/y: 44 (40) in 2030; **111 (101),** incl. **32 from cover crops, in 2040**; 165 (150) in 2050.
Potential for 2040: **67%** via anaerobic digestion, **33%** via biomass thermal gasification.

EBA Statistical Report 2024 (European Biogas Association) https://www.europeanbiogas.eu/eba-statistical-report-2024/

Biomethane potential per feedstock type in European countries in 2040



Expected **leaders** in biomethane production from intermediate/cover crops in **2040:**

Spain – 5.7 bcm/y
France – 5.5 bcm/y
Italy – 4.4 bcm/y
Germany – 3.5 bcm/y

Biogases towards 2040 and beyond. Guidehouse, EBA, 2024. https://guidehouse.com/-/media/new-library/services/sustainability/documents/2024/biogases-towards-2040-and-beyond.ashx

Potential of biomethane production from intermediate crops in Europe until 2050 considering the climate zone type of different regions

Percentages of land dedicated to sequential cropping assumed in the conservative and maximum scenarios

Climate (countries)[1)]	Conservative scenario: share of land under the summer crops[2)] intended for sequential cropping[4)]	Land area intended for sequential cropping, 1000 ha	
		Conservative scenario: 20%[3)]	Maximal scenario: 80%[3)]
Mediterranean (Central and Southern Spain, Portugal, Southern France, Italy, Greece, Albania)	**23%**	2651	10604
Atlantic (Central and Northern France, Ireland, United Kingdom, Belgium, the Netherlands)	**22%**	3943	15773
Continental (Germany, Luxemburg, Denmark, Poland, Austria, Switzerland, the Czech Republic, Slovakia, Hungary, Romania, Bulgaria, the Balkan area)	**31%**	8945	35781

1. *Countries of the* ***Boreal*** *region (Norway, Sweden, Finland, Estonia, Latvia, and Lithuania) were* ***not included*** *in the study as their climate conditions are not suitable for sequential cropping.* ***2.*** *Maize, sorghum, soybean, sunflower, and maize for silage.* ***3.*** *Assumed share of the total area under main crops.*
4. *Expert estimation. A single conservative value 20% was adopted for all the climate types.*

Study by Belgium experts from Ghent University (2021) https://doi.org/10.3390/Agronomy11112102

Potential of biomethane production from intermediate crops in Europe until 2050 considering the climate zone type of different regions (2)

Indicators	Regions of Europe by climate type		
	Mediterranean	Atlantic	Continental
Area under summer sequential crops, 1000 ha:			
- conservative scenario	1326	1972	4473
- maximum scenario	6513	9612	19026
Area under winter sequential crops, 1000 ha:			
- conservative scenario	1326	1972	4473
- maximum scenario	4092	6161	16754
Biogas yield, m^3/ha:			
summer sequential crops	8925	6248	7140
winter sequential crops	6050	4066	4418
Potential of biomethane production, bcm/y:			
- conservative scenario*	**9.9**	**10.2**	**25.8**
- maximum scenario**	37.9	42.5	104.9

** **45.9** bcm/y in total. For comparison: **31.8** bcm/y in 2040 according to EBA report 2024. ** **185.4** bcm/y in total.*

Study by Belgium experts from Ghent University (2021) https://doi.org/10.3390/Agronomy11112102

EU countries	Maximum biomethane potential from novel crop rotations (bcm)	CORRECTION FACTORS						Deliverable biomethane potentials from novel crop rotations (bcm)
		Food vs fuel	Biomass competition	Arable Compatibility	Arable land readiness*	Climate impact	Uncertainty	
Austria	0.2	100%	98%	89%	78%	Unknown	80%	0.1
Belgium	0.9	95%	98%	71%	78%		80%	0.4
Bulgaria	2.8	100%	98%	94%	78%		80%	1.6
Croatia	1.1	95%	98%	92%	78%		80%	0.6
Cyprus	0.2	100%	98%	78%	78%		80%	0.1
Czechia	2.2	100%	98%	92%	78%		80%	1.2
Denmark	1.9	95%	98%	86%	78%		80%	0.9
Estonia	0.1	90%	98%	90%	78%		80%	0.0
Finland	0.7	90%	98%	84%	78%		80%	0.3
France	18.4	95%	98%	89%	78%		80%	**9.5**
Germany	9.5	100%	98%	88%	78%		80%	**5.1**
Greece	2.8	100%	98%	84%	78%		80%	1.4
Hungary	3.7	100%	98%	91%	78%		80%	2.1
Ireland	0.2	90%	98%	95%	78%		80%	0.1
Italy	12.7	100%	98%	83%	78%		80%	**6.4**
Latvia	0.2	90%	98%	90%	78%		80%	0.1
Lithuania	0.3	90%	98%	89%	78%		80%	0.1
Luxembourg	0.1	100%	98%	96%	78%		80%	0.1
Malta	0.0	100%	98%	68%	78%		80%	0.0
The Netherlands	0.8	90%	98%	59%	78%		80%	0.3
Poland	10.0	100%	98%	88%	78%		80%	**5.4**
Portugal	0.6	95%	98%	70%	78%		80%	0.2
Romania	6.2	100%	98%	95%	78%		80%	3.6
Slovakia	0.1	100%	98%	92%	78%		80%	0.1
Slovenia	0.1	100%	98%	94%	78%		80%	0.1
Spain	10.4	95%	98%	61%	78%		80%	3.7
Sweden	0.8	90%	98%	89%	78%		80%	0.4
TOTAL EU27	87.0							**44.0**

Potential of biomethane production from sequential and rotational crops in the EU-27

Assessment by **Task Force 3.1 of the Biomethane Industrial Partnership** (2025) **builds on** the study by Ghent University and BiogasDoneRight model and applies a **novel** approach to modelling biomethane potential from **novel** crop rotations.

* As soil health improves across Europe, the deliverable biomethane potential will also increase.

Biomethane Industrial Partnership (April 2025) https://bip-europe.eu/wp-content/uploads/2025/04/BIP-Task-Force-3.1_Biomethane-Potential-Novel-Cropping-Systems_April2025.pdf

Assessment of the potential for biomethane production from intermediate crops in Ukraine

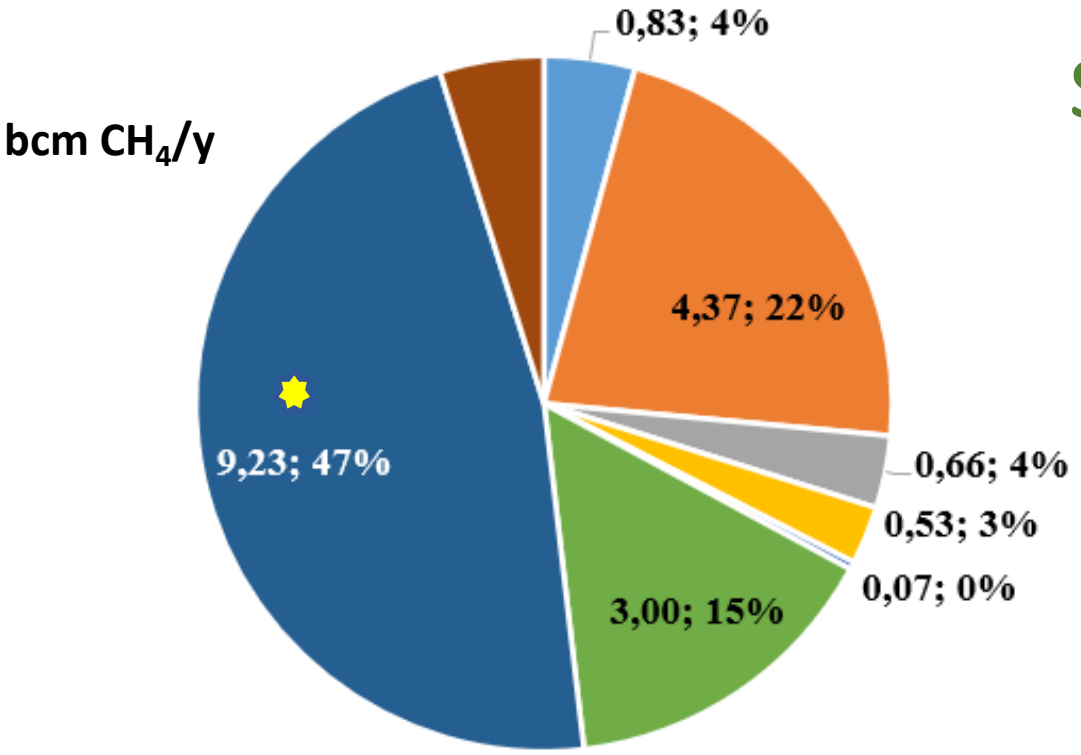
INDICATOR	VALUE	COMMENT
Sown area, Mha (I)	**28.4**	Data for 2021.
Share of the sown area intended for growing intermediate crops (II), %	**20**	The values are assumed considering data of the study on «The Role of Sequential Cropping and Biogasdoneright™ in Enhancing the Sustainability of Agricultural Systems in Europe» (2021). *Study by Belgium experts from Ghent University* *https://doi.org/10.3390/Agronomy11112102*
Average yield of intermediate crops, t dry matter/ha/y (III)	**5**	
Yield of biogas from intermediate crops, m^3/t dry matter (IV)	**570**	
Concentration of biomethane in biogas (V), %	**57**	According to the figure from the biomethane potential assessment by Gas for Climate (2022). *https://gasforclimate2050.eu/wp-content/uploads/2023/12/Guidehouse_GfC_report_design_final_v3.pdf*
POTENTIAL OF BIOMETHANE PRODUCTION FROM INTERMEDIATE CROPS, bcm/y (I× II/100 × III × IV × V/100)	**9.23**	The conservative approach assessment. The higher input data (area under intermediate crops and their yield) will result in the higher potential.

Assessment of the total potential for biomethane production in Ukraine

Types of feedstocks for biomethane production	Theoretical potential, bcm CH_4/y	The economic potential (available for energy)	
		Share of the theoretical potential, %	bcm CH_4/y
Animal husbandry waste (manure)	1.04	80	0.83
Post-harvest crop residues	16.79	26	4.37
By-products of food industry	1.69	39	0.66
Municipal solid waste	0.70	75	0.53
Sewage sludge (communal treatment facilities)	0.07	100	0.07
Energy crops (maize silage from 1 Mha)	3.00	100	3.00
Intermediate/cover crops	**9.23**	**100**	**9.23**
Wood biomass, woody/grassy energy crops[2)]	9.51	10	0.95
BIOMETHANE, total	**42.03**	**47**	**19.64**

1) *Excluding the temporarily occupied territories of Ukraine as of 2021.* ***2)*** *10% of the theoretical potential of wood biomass and woody/grassy energy crops (willow, poplar, miscanthus) is allocated to biomethane production through thermochemical gasification of biomass.*

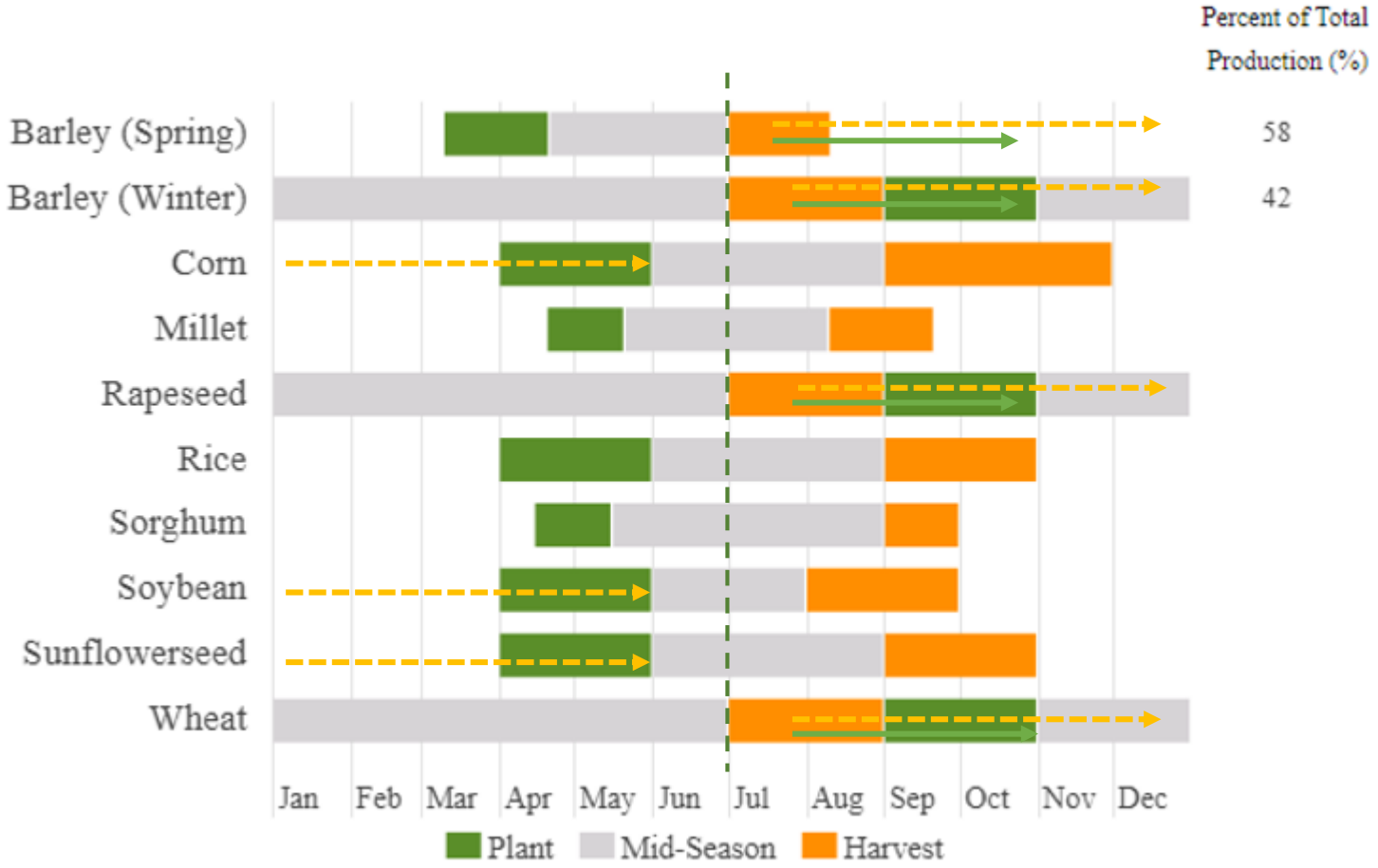
Structure of the economic potential of biomethane production in Ukraine



Total: <u>19.6</u> bcm CH_4/y

https://phys.org/news/2023-09-agriculture-crops-mixtures-unexpected-results.html
https://thebreakthrough.org/issues/food-agriculture-environment/cover-crops-climate-hype

Calendar for the cultivation of main agricultural crops in Ukraine



In addition to biological interaction of intermediate crops with forecrops and after-crops and their impact on soil fertility, it is important to determine the **periods** when the fields are **free** from main crops, but at the same time, there are **favourable agroclimatic conditions** for the plant vegetation.

The following crops can be used as **intermediate** crops for biomass production in the **current** year for biogas/biomethane:

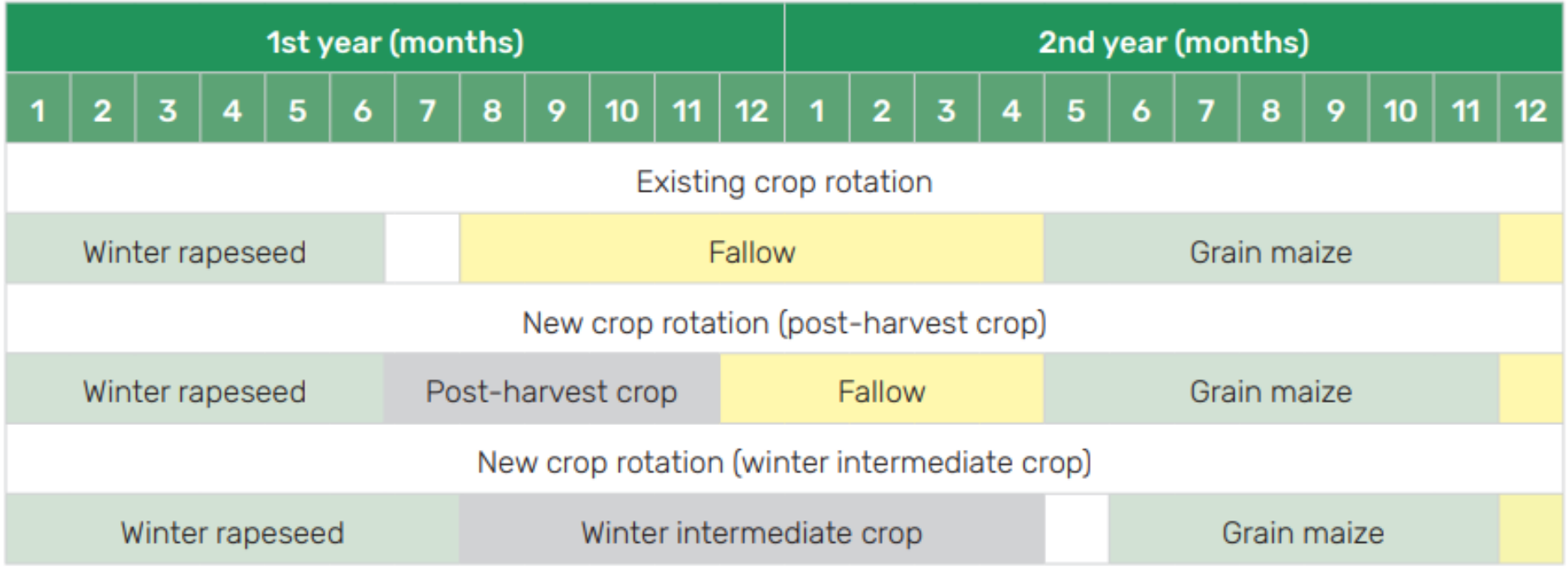
- **spring cereals** (after early preceding crops),
- **maize** (early-maturing hybrids under favourable conditions),
- **sorghum**, and **vetch,**
- **amaranth** is also promising due to its drought resistance, resilience, and ability to quickly build up significant biomass for obtaining green mass.

For the early biomass harvesting in the **next** year, **winter** intermediate crops such as **winter rye** for green mass (KWS Propower, KWS Magnifico), **triticale** (Veleten), **winter wheat**, and **winter barley** (at early stages of development) can be considered.

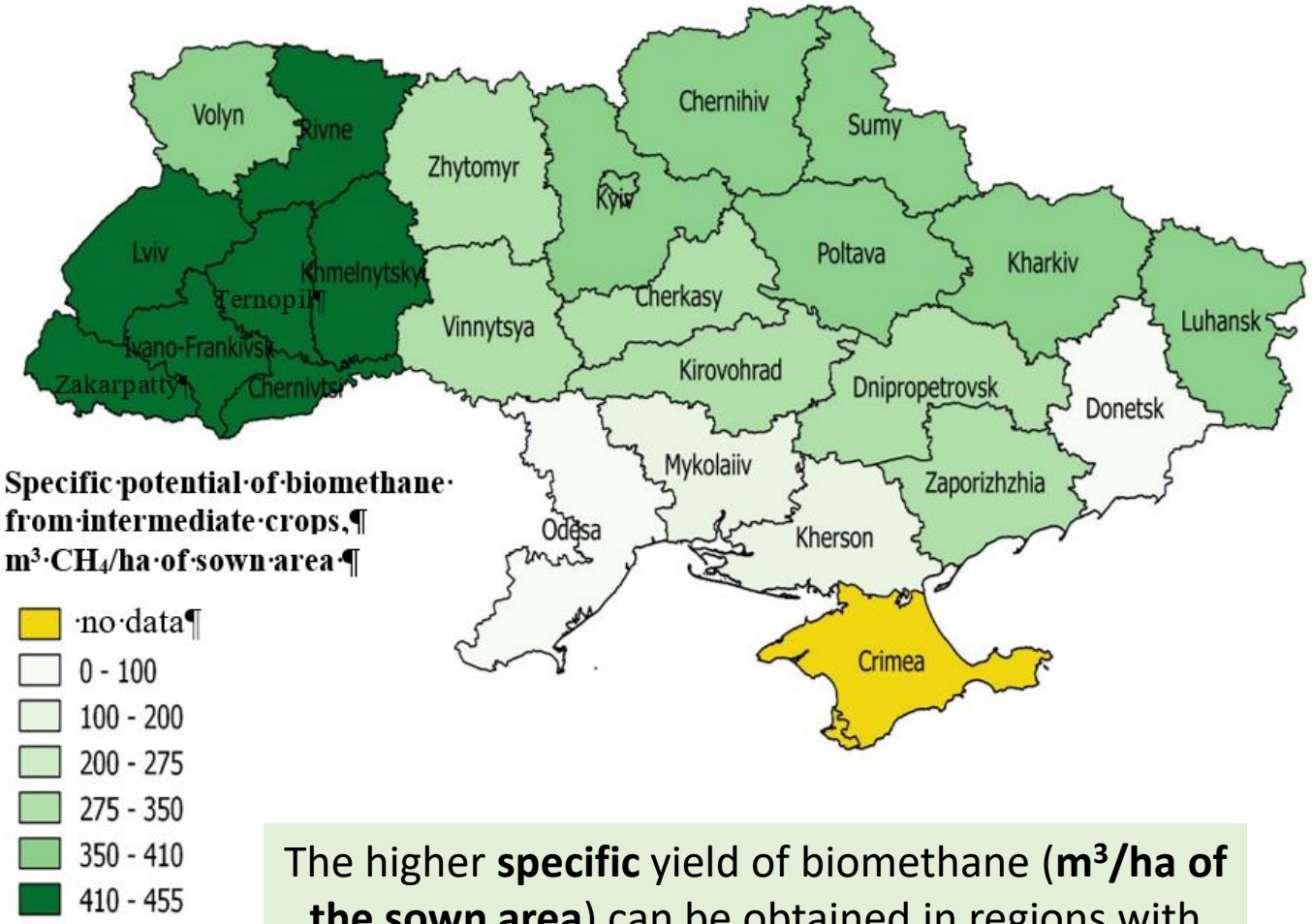
An example of introducing intermediate crops into an existing crop rotation

The example of growing intermediate crops for biogas in the existing crop rotation between winter rapeseed and grain maize on 2000 ha in the Forest-Steppe zone

It is proposed to sow **post-harvest** crops in **July** on 1000 ha after winter rapeseed which will be harvested in June-July, and then to sow **winter intermediate** crops in August on the remaining 1000 ha area after winter rapeseed. **Post-harvest** crops will be harvested in **October-November. Winter intermediate** crops will be harvested in **May** before the start of sowing maize. The choice of intermediate crops is determined by their ability to **quickly form green mass** from July to November for post-harvest crops and from August to May for winter intermediate crops.



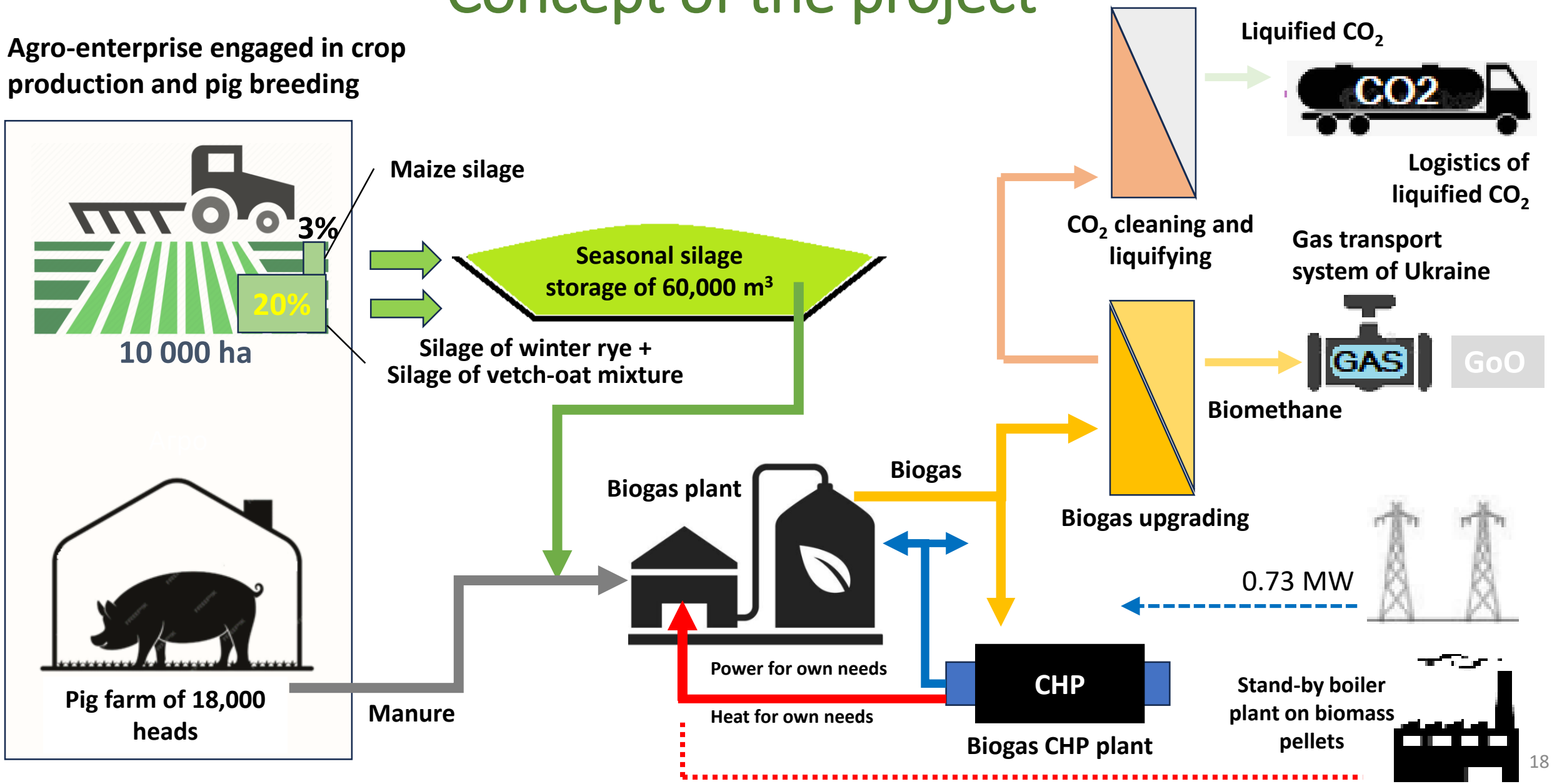
The specific economic potential of biomethane production from intermediate crops in Ukraine's regions



The higher **specific** yield of biomethane (**m³/ha of the sown area**) can be obtained in regions with higher precipitation: Ivano-Frankivsk, Lviv, Rivne, Ternopil, Khmelnytskyi and Chernivtsi oblasts.

Regions (oblasts)	Area under intermediate crops, 1000 ha		Approximate yield of intermediate crops, t dry matter/ha		Biomethane amount, million m³ CH_4/y
	winter crops	post-harvest crops	winter crops	post-harvest crops	
Vinnytsia	165	165	7.0	3.5	564
Volyn	61	61	8.0	3.5	229
Dnipropetrovsk	197	197	7.0	3.5	673
Donetsk	52	–	5.2	–	88
Zhytomyr	115	–	6.0	–	225
Zakarpattia	17	17	9.0	4.5	76
Zaporizhzhia	171	171	8.0	3.5	640
Ivano-Frankivsk	38	38	9.0	5.0	174
Kyiv	119	119	8.0	3.5	445
Kirovohrad	171	171	7.0	3.5	582
Luhansk	86	86	8.0	3.5	320
Lviv	71	71	9.0	5.0	321
Mykolaiv	160	–	6.0	–	312
Odessa	92	–	5.2	–	156
Poltava	173	173	8.0	3.5	647
Rivne	62	62	9.0	5.0	282
Sumy	121	121	9.0	3.5	491
Ternopil	84	84	9.0	5.0	382
Kharkiv	182	182	8.0	3.5	681
Kherson	148	–	6.0	–	288
Khmelnytskyi	121	121	9.0	5.0	548
Cherkasy	122	122	7.0	3.5	415
Chernivtsi	31	31	9.0	5.0	140
Chernihiv	135	135	9.0	3.5	550
TOTAL					9229

Concept of the project



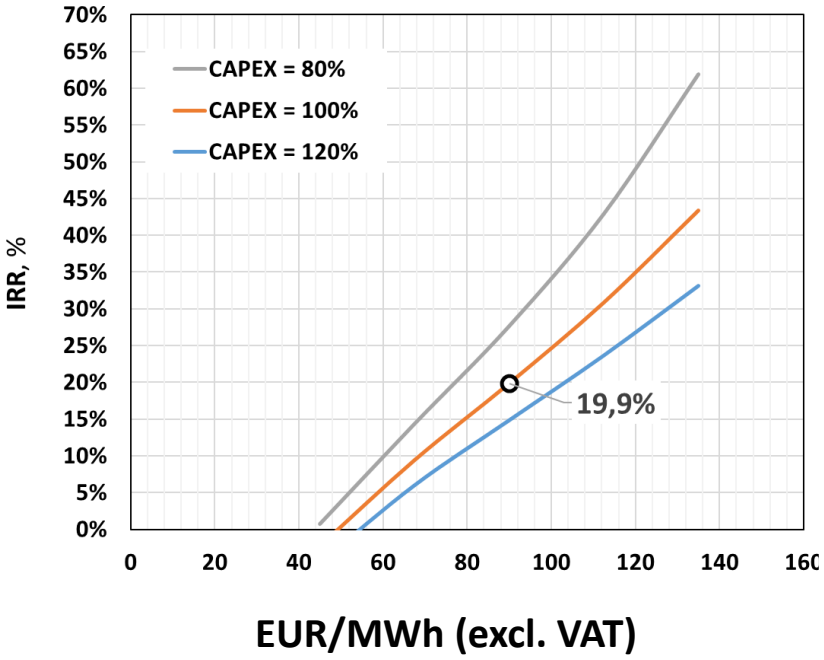
Project cost-effectiveness indicators

INDICATOR	UNIT	VALUE
Investments (CAPEX), including:	million EUR	14.22
Borrowed funds		8.53
Own funds		5.69
Operating expenses (OPEX), including:	million EUR/y (excluding VAT)	1.98
Feedstock		1.21
Operating expenses		0.29
Target product logistics		0.39
Revenue		4.87
Biomethane into gas-transport system		3.92
Liquefied CO_2		0.75
Digestate		0.19
Net present value (NPV)	million EUR	5.78
Internal return rate (IRR)	%	19.9%
Profitability index (PI)	-	0.41
Simple payback period (SPP)	years	5.9
Discounted payback period (DPP)	years	7.8

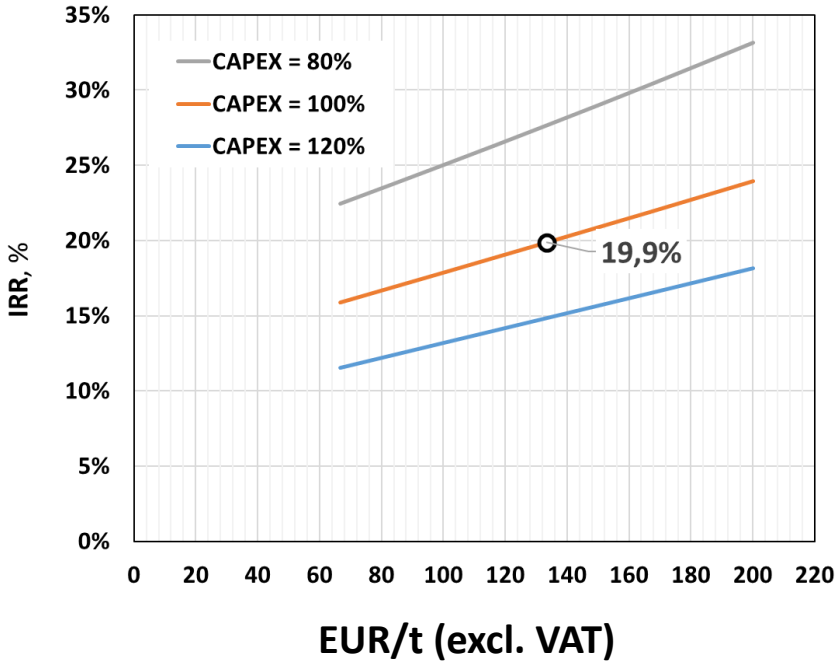
The calculated averaged **GHG emissions** during the biomethane life cycle are **negative** (**-13.00 gCO_{2eq}/MJ**). The required assumptions are: about **25%** of biomethane is obtained from **manure;** CO_2 after biogas upgrading is supplied to a consumer where it **replaces** CO_2 obtained from fossil fuels.

Sensitivity analysis

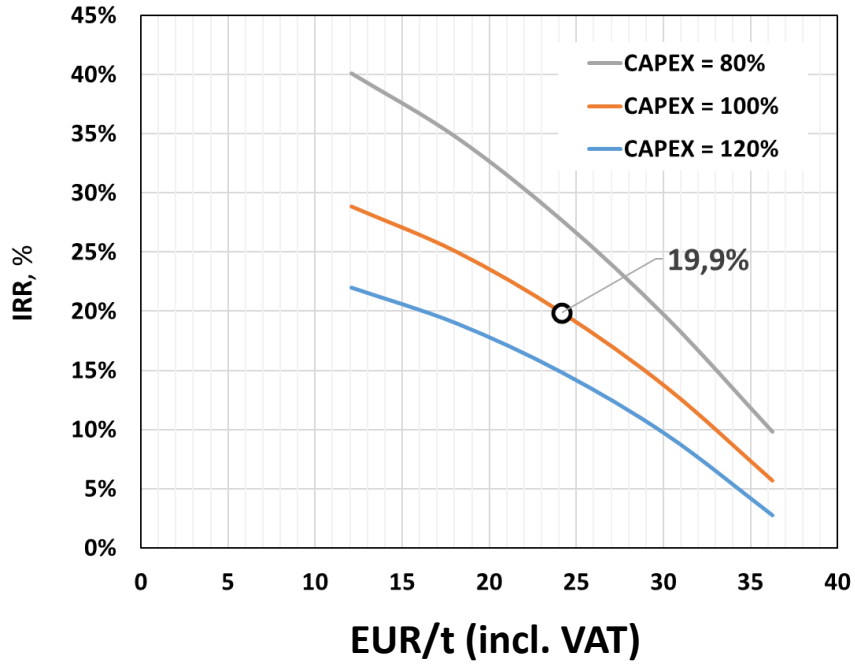
Impact of biomethane price



Impact of CO_2 price



Impact of the feedstock price



- The project profitability is significantly **affected** by the **sale price of biomethane** and the **feedstock price**, and to a lesser extent by the sale price of liquefied CO_2.
- A **decrease** in the sale price of biomethane by only 10% to 81 EUR/MWh leads to an **increase** in the discounted payback period to 9.7 years with an IRR of 15.7%.
- The project is also **sensitive** to an **increase** in CAPEX. With the increase in CAPEX by 20%, the project may be on the verge of investment attractiveness with a discounted payback period of 10.3 years and an IRR of 14.8%.

Conclusions

- Intermediate crops are a large potential source of **sustainable biomass**, including that for **biomethane** production.
- It is a **perspective direction** for bioenergy of the EU and Ukraine. By 2040, intermediate crops may become the **main feedstock** for biomethane production via anaerobic digestion in the EU. Biomethane from intermediate crops accounts for **the biggest share** in the general structure of biomethane production potential in Ukraine.
- Further studies with transition to some **practical activities** are required in Ukraine.

- The project on biomethane production from the silage of intermediate and cover crops is quite **sensitive** to changes in key economic parameters.
- **The key** to the successful implementation of such projects may be to guarantee a satisfactory long-term biomethane sale price and to find more profitable markets for liquefied carbon dioxide.
- Reducing investment in the project would make it more **economically stable**; however, the probability of a significant (15-20%) reduction is estimated as **low**.

https://agroelita.info/pidsiv-pokryvnoi-kultury-iak-zasib-polipshennia-fizyko-khimichnykh-vlastyvostey-gruntu/

Thank you for your attention!

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