ANAEROBIC DIGESTION AS A CARBON CAPTURE, STORAGE, AND UTILIZATION TECHNOLOGY

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Figure extracted from www.freepik.es/vectores/biogas

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About AgRefine European Training Network

- Green biorefineries
- 15 PhD students, interdisciplinary projects
- 3 work packages

Technology

System-level analysis

Value chains

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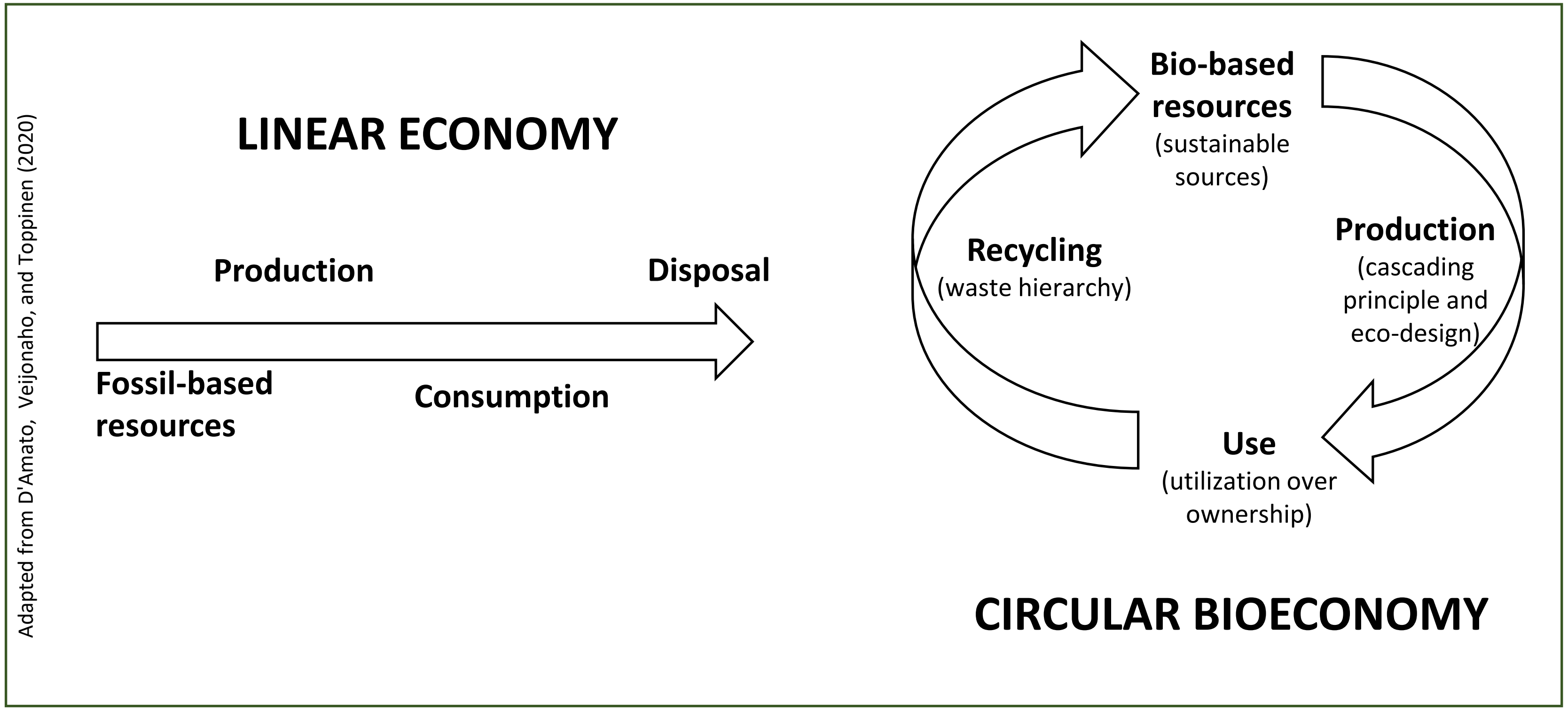
 E2DT

Transition to the circular bioeconomy



Adapted from D'Amato, Veijonaho, and Toppinen (2020)

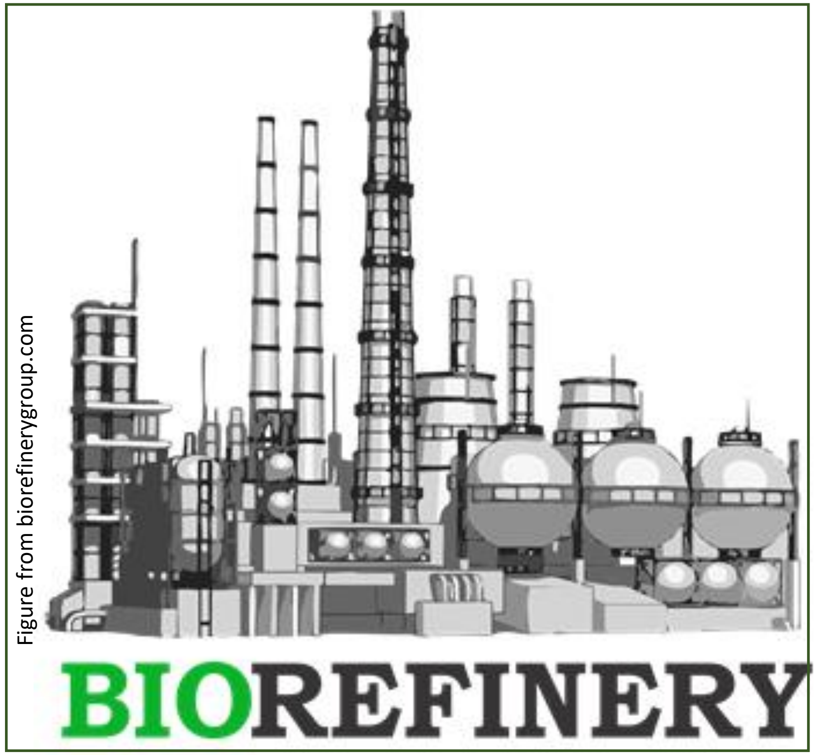


Figure from biorefinerygroup.com

Biorefinery

A biorefinery is an industrial site that sustainably transforms biomass into human and animal food products, biomaterials, biofuel, and chemical products with high value-added, such as cosmetics (Schieb et al., 2015).

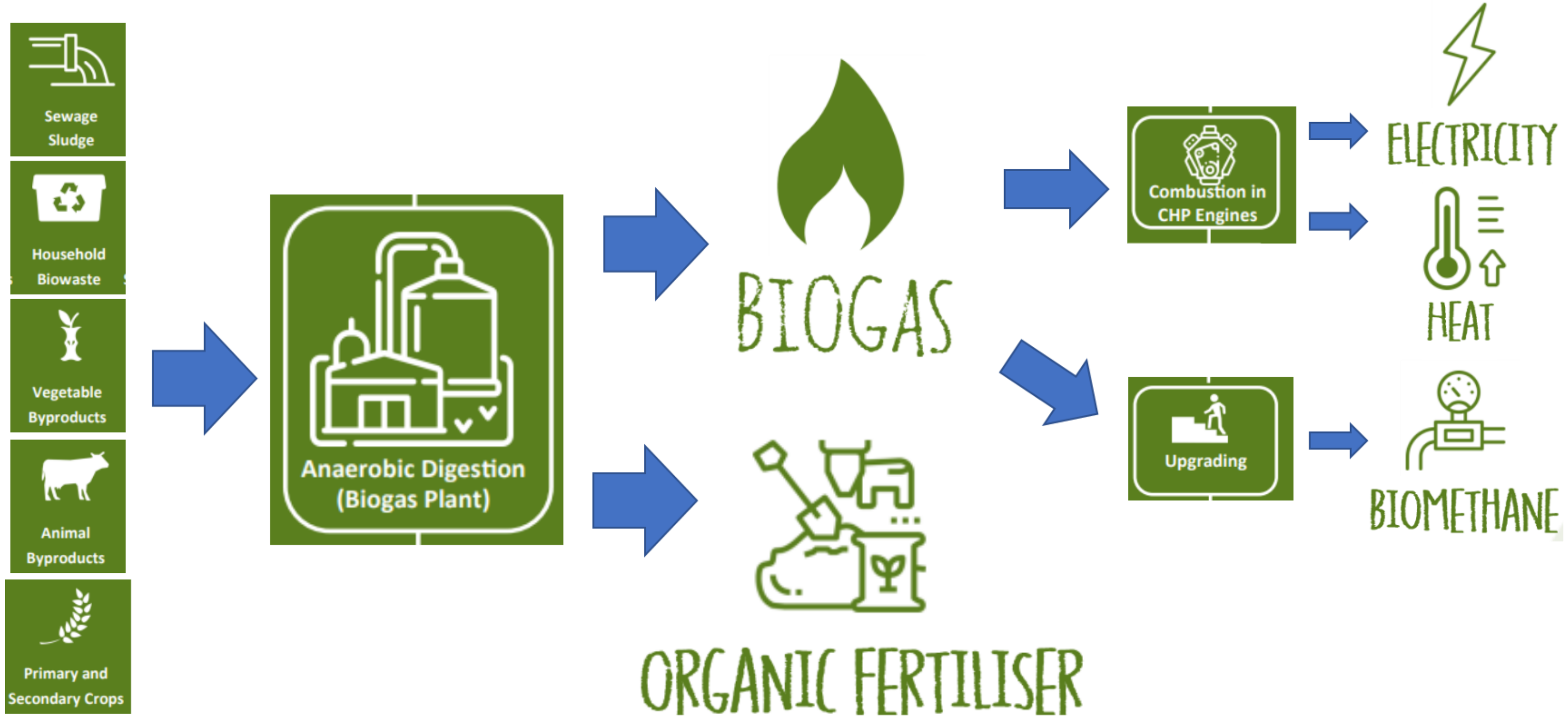
"A biorefinery is the sustainable processing of biomass into a spectrum of marketable products (food, feed, materials, chemicals) and energy (fuels, power, heat)" (IEA Bioenergy Task 42).

The IEA Bioenergy Task 42 classifies biorefineries according to their feedstocks, processes, platforms and products.

In the green biorefinery concept the integration of anaerobic digesters into biorefineries as a valorisation technique was proposed to produce lactic acid, amino acids, fibres, and energy (Kromus et al., 2004).

Biogas Plant

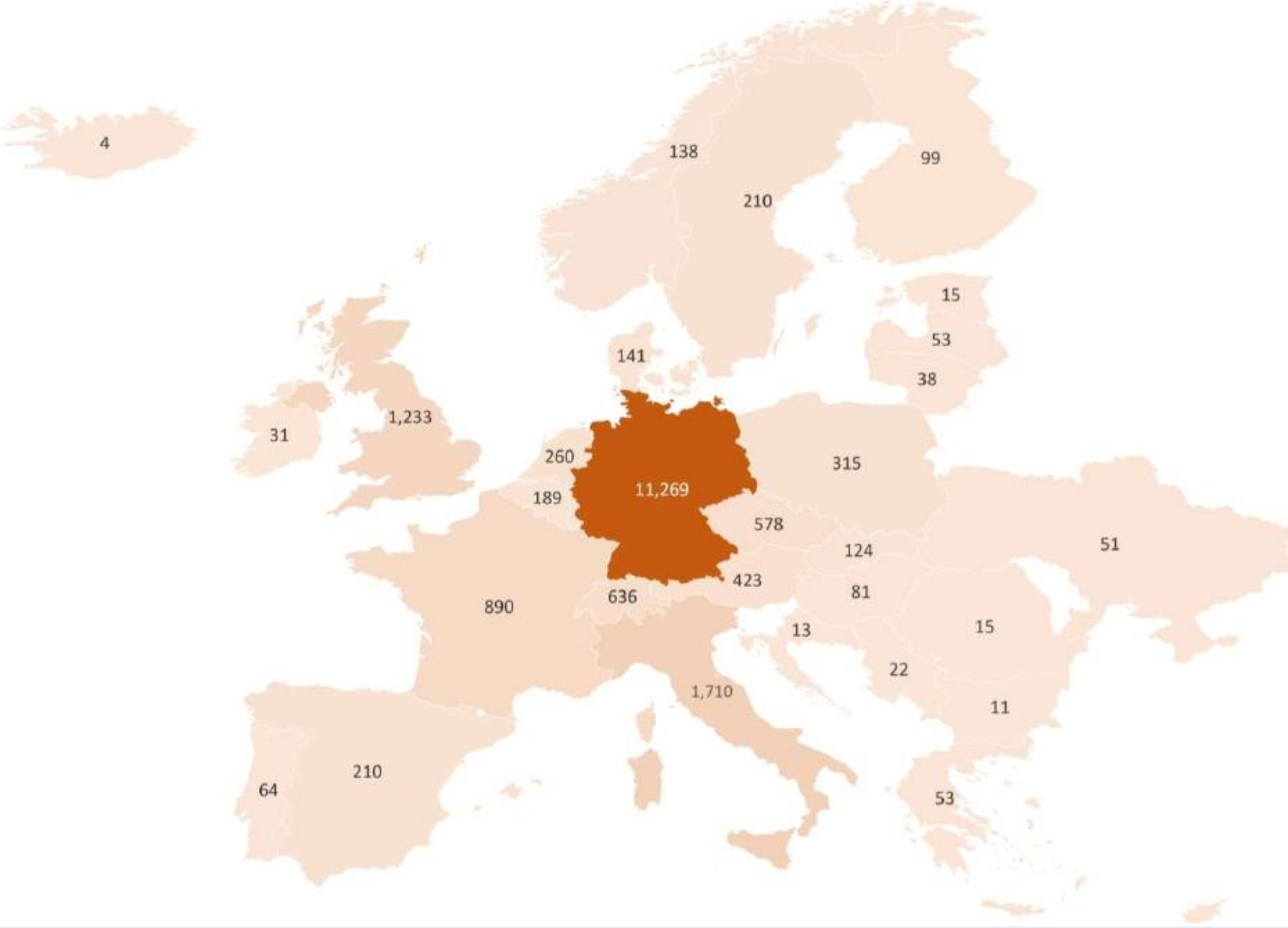
A biogas plant is a facility where organic materials are transformed into biogas to be utilized as energy and heat or be upgraded to grid quality gas (biomethane > 96 %).



Adapted from (EBA, 2019)

Biogas Plants in Europe 2020

Germany	**11,269**
Italy	1,710
United Kingdom	1,233
France	890
Switzerland	636
Czech Republic	578
Austria	423
Poland	315
Netherlands	260
Sweden	210
Spain	210
Belgium	189
Denmark	141
Norway	138
Slovakia	124
Finland	99



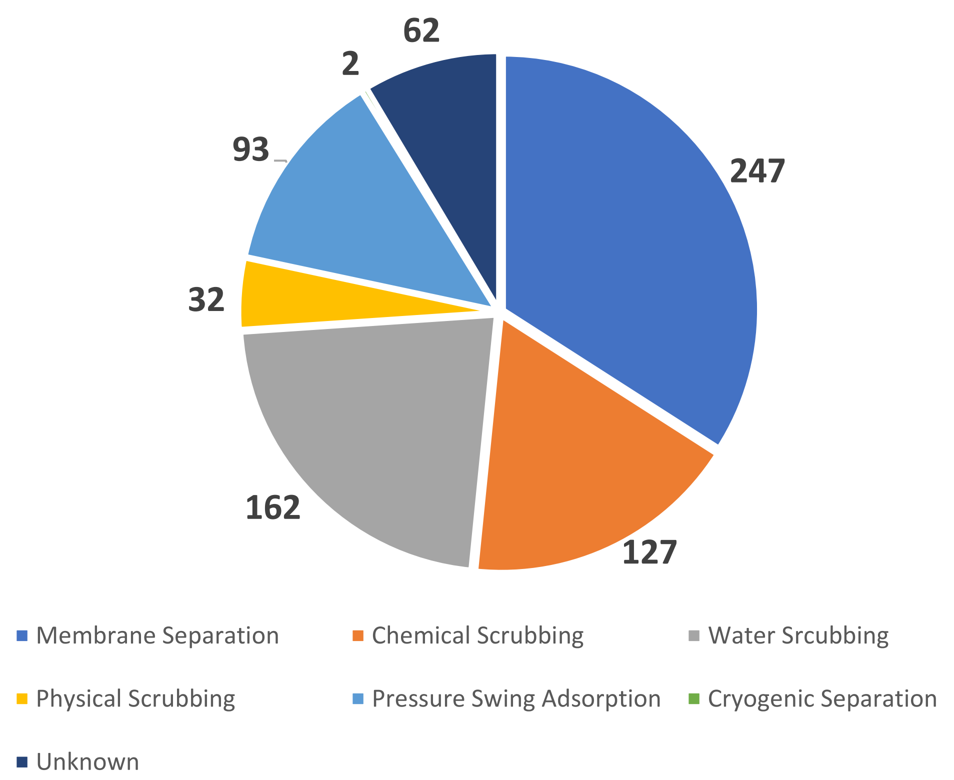
81	Hungary
64	Portugal
53	Greece
53	Latvia
51	Ukraine
38	Lithuania
31	Ireland
30	Luxembourg
23	Slovakia
22	Serbia
15	Romania
15	Estonia
14	Cyprus
13	Croatia
11	Bulgaria
4	Iceland

Total 18,425

Data extracted from (EBA, 2020)

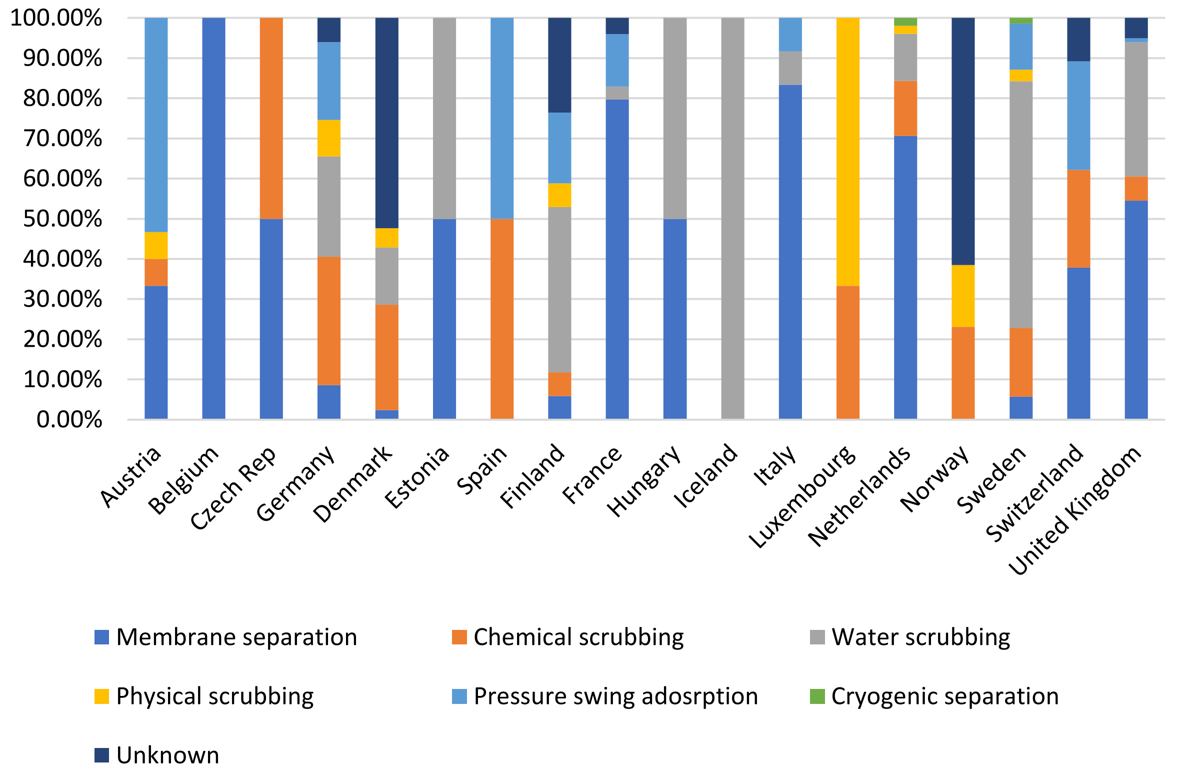
Biogas upgrading technologies

Relative use of separation technologies in 2019



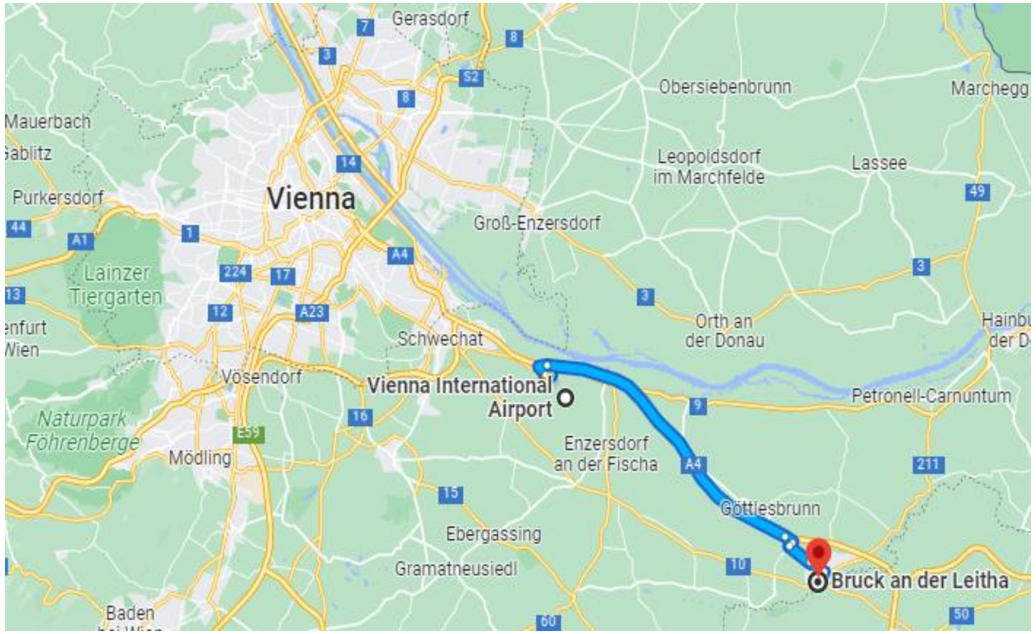
Adapted from (EBA, 2020)

Biogas Upgrading Technologies by country



Adapted from (EBA, 2020)

Biogas Plant in Bruck an der Leitha



- 7,660 inhabitants
- 23.81 km^2
- 25 km from Vienna's airport

- Built in 2004
- Retrofitted to biomethane plant in 2008
- 5,200,000 m^3 of biogas are produced and upgraded,
- 3,300,000 m^3 of biomethane and
- 1,900,000 m^3 of carbon dioxide

CO_2 Enrichment

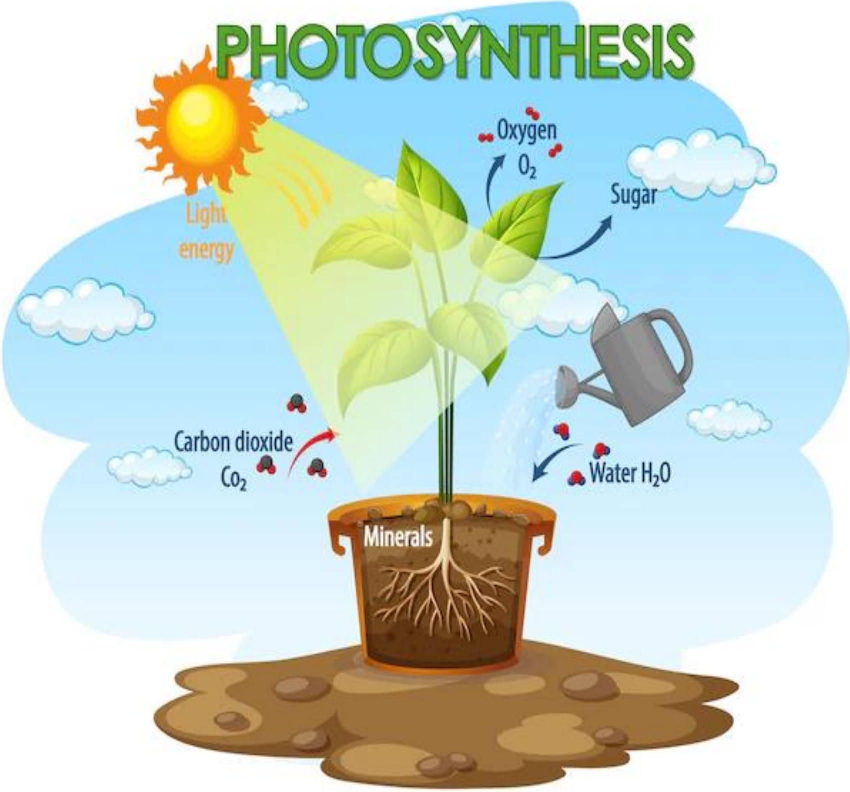


Figure extracted from geeksforgeeks.org


Figure extracted from growerssupply.com

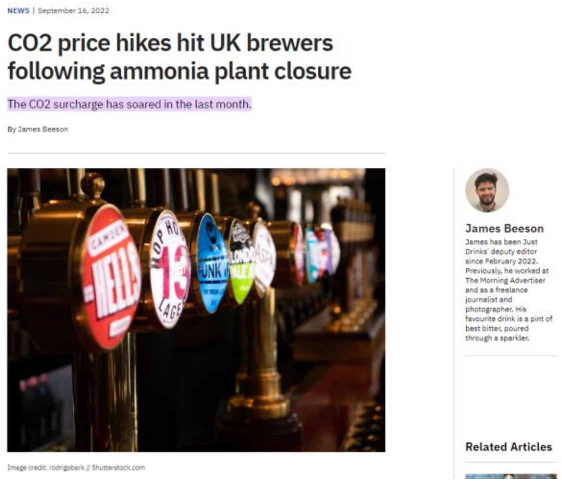
CO_2 concentration

- In outside air: 416 ppm[1].
- In closed greenhouses with little ventilation: 200 ppm[2].
- Optimal CO_2 concentration for growth and yield: 700 - 900 ppm[2].
- Crop saturation point: 1,000 - 1,300 ppm[2].
- 5,000 ppm are harmful for humans[3].

[1] gml.noaa.gov; [2] Blom et al., (2002); [3] Daisey, Angell and Apte (2003)

CO_2 shortage

August 25th



September 16th

September 16th

September 22nd

- “As <u>fertiliser factories are shutting down due to energy costs</u>, a shortage of concentrated CO_2 is looming, and brewers and other food companies are sounding the alarm that their trade will be particularly affected.”
- “Fertiliser production is being reduced across Europe due to high gas prices. This is having a knock-on impact on the availability of carbon dioxide. Meat producers are calling for urgent government intervention.”

Climatological data

Monthly average climatological data of Bruck an Der Leitha

Month	Solar Radiation (MJ)	Daily Daylight (h)	Air Temperature (°C)	Relative Humidity (%)	Wind Speed (m/s)	Cloudiness (%)
January	4.68	8.9	-3 / 3	89	4.43	57
February	7.92	10.3	-2 / 5	84	4.65	57
March	12.6	12	2 / 10	72	4.52	56
April	18	13.7	6 / 16	64	4.34	52
May	21.96	15.2	10 / 20	65	4.07	49
June	23.76	16	14 / 24	59	3.93	43
July	23.76	15.6	16 / 26	55	3.80	35
August	20.52	14.2	15 / 25	54	3.62	37
September	15.12	12.5	11 / 21	64	3.80	45
October	9.72	10.8	7 / 14	76	3.98	51
November	5.4	9.2	2 / 8	88	4.16	61
December	3.96	8.4	-1 / 3	88	4.25	61

Data extracted from (WeatherSpark, 2022)

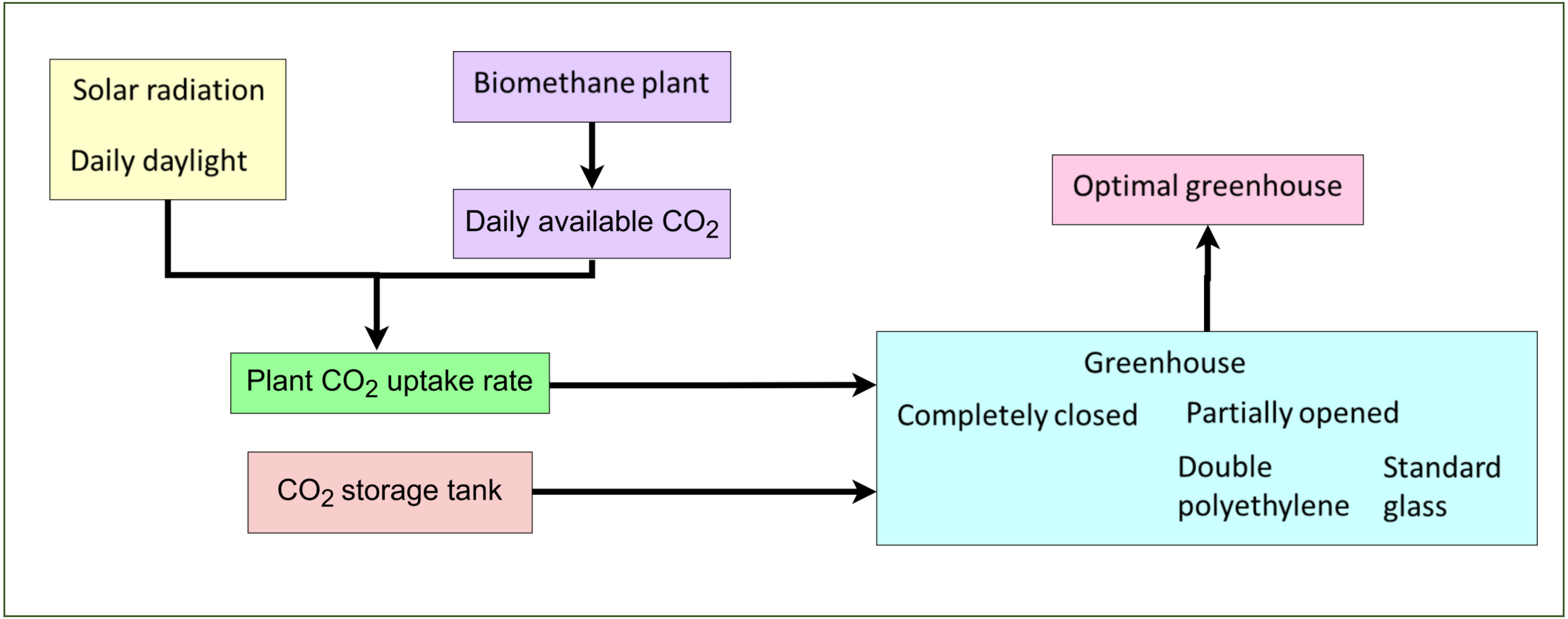
Simplified Calculation

Potential yearly CO_2 use on a monthly basis based on sunshine hours at Bruck an der Leitha

Month	Number of hours applied (h)	CO_2 Applied Rate (kg/ha/h)					
		Completely Closed			Partially Opened		
		12	18	24	45	65	90
January	275.9	3,310.8	4,966.2	6,621.6	12,415.5	17,933.5	24,831
February	288.4	3,460.8	5,191.2	6,921.6	12,978	18,746	25,956
March	372	4,464	6,696	8,928	16,740	24,180	33,480
April	411	4,932	7,398	9,864	18,495	26,715	36,990
May	471.2	5,654.4	8,481.6	11,308.8	21,204	30,628	42,408
June	480	5,760	8,640	11,520	21,600	31,200	43,200
July	483.6	5,803.2	8,704.8	11,606.4	21,762	31,434	43,524
August	440.2	5,282.4	7,923.6	10,564.8	19,809	28,613	39,618
September	375	4,500	6,750	9,000	16,875	24,375	33,750
October	334.8	4,017.6	6,026.4	8,035.2	15,066	21,762	30,132
November	276	3,312	4,968	6,624	12,420	17,940	24,840
December	260.4	3,124.8	4,687.2	6,249.6	11,718	16,926	23,436
Total (kg)		53,622	80,451	107,244	201,082.5	290,452.5	402,165
Greenhouse Area (Ha)		17.92	11.95	8.96	4.78	3.31	2.39

Based on Blom et al., (2002)

Detailed calculation



Detailed calculation

Summary of results of detailed calculation

Concept	Completely Closed	Partially Opened	
		Double Polyethylene	Standard Glass
Greenhouse with No CO_2 Storage (Ha)	7.03	4.82	2.81
Greenhouse with CO_2 Storage (Ha)	11.31	6.97	3.85
CO_2 Storage (m^3)	368,989	276,515	232,791
CO_2 Uptake Rate ($kg/h/100m^2$)	0.12-0.24	0.25-0.35	0.5-0.6

Calculation comparison

Partially Open Greenhouse

Simplified Calculation (Ha)		**Detailed Calculation (Ha)**			
		Standard Glass		Double Polyethylene	
High Rate	Low Rate	No CO_2 Storage	CO_2 Storage	No CO_2 Storage	CO_2 Storage
2.39	**4.78**	**4.8**	7	**2.81**	3.85

Figure from islandgrower.com

Completely Closed Greenhouse

Simplified Calculation (Ha)		**Detailed Calculation (Ha)**	
High Rate	Low Rate	No CO_2 Storage	CO_2 Storage
9	18	7	11

Figure from ag.umass.edu

Conclusions

Optimal greenhouse's

Capacity designs → **Evaluated** → for **CO_2 enrichment**

Area values → **Obtained** →

- **Completely closed greenhouses**
- **Partially opened greenhouses**
  - Standard glass walls
  - Double polyethylene walls

- Simplified methods allow quantifying the potential greenhouse CO_2 enrichment for greenhouse farming.
- Another use for the CO_2 by-product of the biomethane plant of Bruck an der Leitha is algae farming.

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PRESENTATION # 019

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THANK YOU FOR YOUR ATTENTION!

QUESTIONS?

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