FACULTY of INFRASTRUCTURE AND ENVIRONMENT
CZESTOCHOWA UNIVERSITY OF TECHNOLOGY

ENVISAFEBIOC
EVIRONMENTAL SAFETY OF BIOSOLIDS IN THE CIRCULAR ECONOMY

NAWA POLISH NATIONAL AGENCY FOR ACADEMIC EXCHANGE
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The problem of biodegradable waste under Polish conditions in the context of environmental safety

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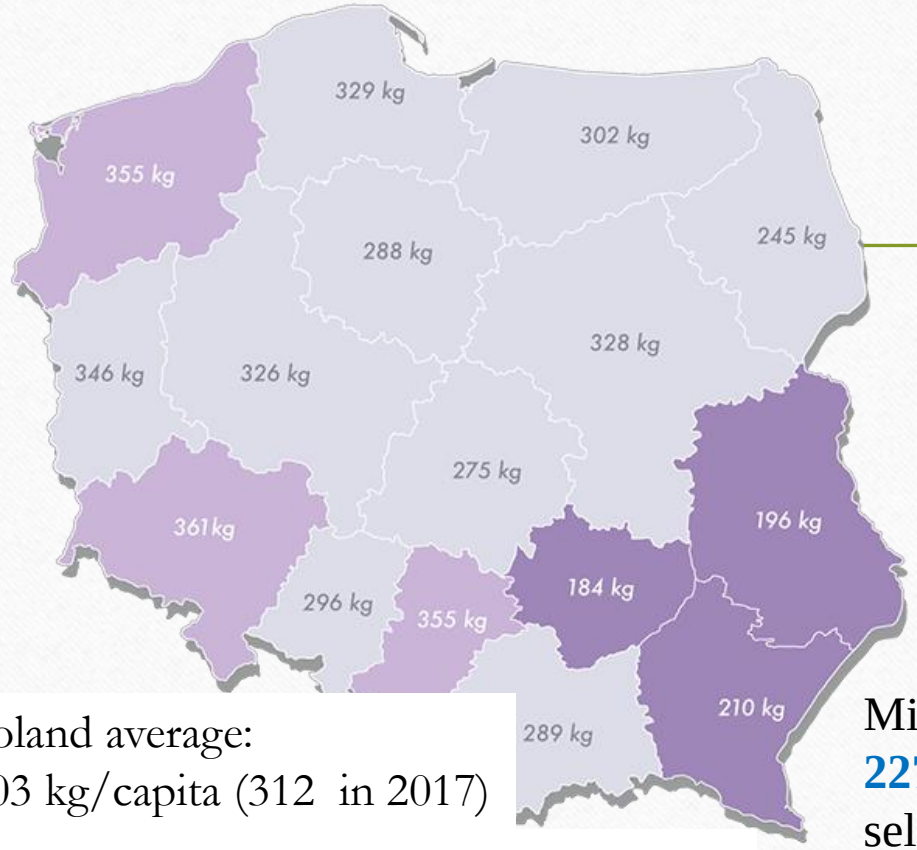
General information about waste management in Poland

Amount of mixed waste (A) and selectively collected municipal waste (B) in Poland in 2016

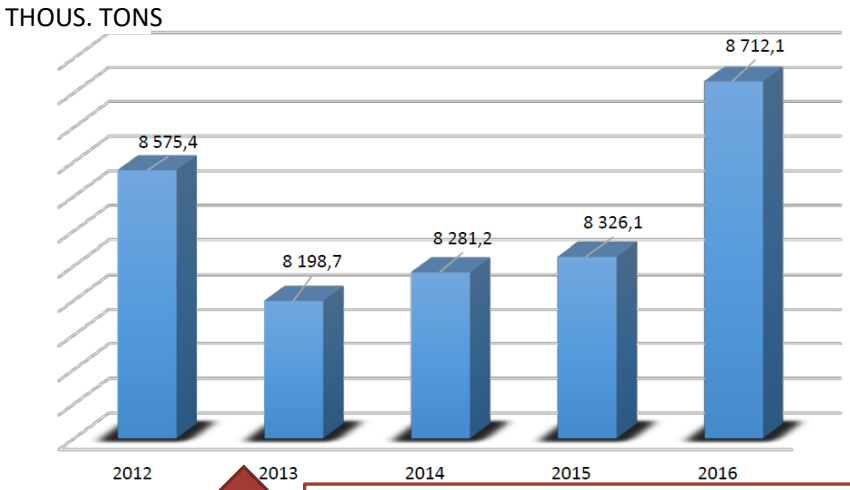
Municipal solid waste - amount per capita



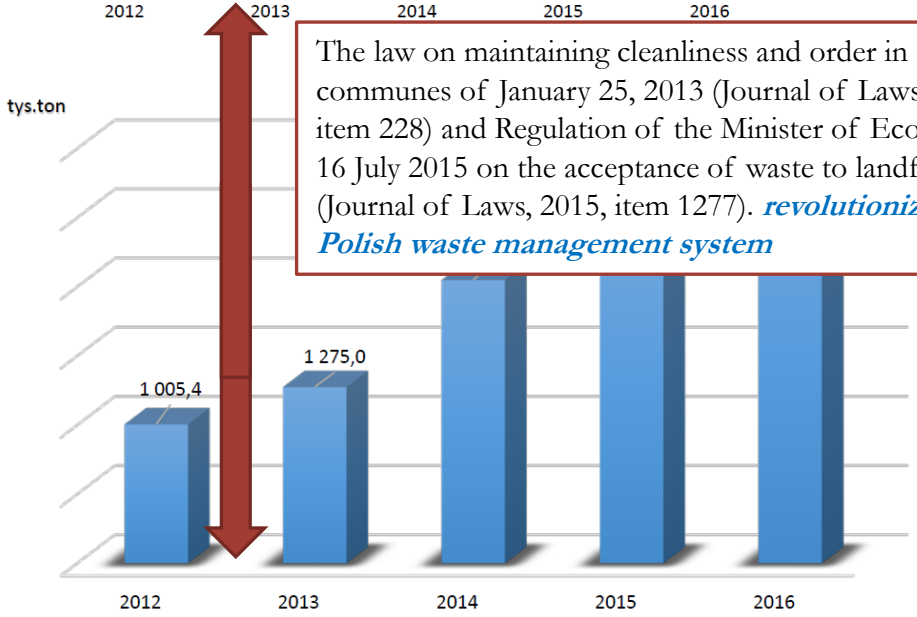
Poland average:
303 kg/capita (312 in 2017)

Total amount of waste generated in 2016
139 961 000 tons
Including MSW:
11 654 000 tons (approx. 8%)

A



B



Mixed waste
227 kg/capita
selectively collected municipal waste
84 kg/capita

The law on maintaining cleanliness and order in communes of January 25, 2013 (Journal of Laws of 2013, item 228) and Regulation of the Minister of Economy of 16 July 2015 on the acceptance of waste to landfills (Journal of Laws, 2015, item 1277). ***revolutionized the Polish waste management system***

486 kg of municipal waste per capita were generated in the EU in 2017.

Source: https://www.teraz-srodowisko.pl/media/infografiki/4292/?mobile; Central Statistical Office (GUS). " Change of municipal waste management system in Poland in 2012-2016" Warsaw 2017; Brzeszczak, A. (2019). Municipal waste management system in Poland-analysis of changes in 2012-2016. *World Scientific News, 125*, 169-180

The main tasks of the communes:

- ensuring the construction, maintenance and operation of own, or joint with other municipalities, regional installations for processing municipal waste,
- covering all property owners in the commune with a municipal waste management system,
- supervision of municipal waste management, including the implementation of tasks entrusted to entities collecting municipal waste from property owners,
- establishment of selective collection of municipal waste covering at least the following waste fractions: paper, metal, plastic, glass and multi-material packaging as well as biodegradable municipal waste, including biodegradable packaging waste, ensuring the achievement of appropriate levels of recycling, preparation for re-use and recovery by other methods, and limiting the mass of biodegradable municipal waste transferred to landfilling.

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Landfill is prohibited if:

Lp.	Parameter	Limit values
1	**Total organic carbon**	5% TS (total solid)
2	**Loss on ignition**	8% TS (total solid)
3	**A gross calorific value**	6 MJ / kg TS (total solid)

Based on: Regulation of the Minister of Economy of 16 July 2015 on the acceptance of waste to landfills (Journal of Laws, 2015, item 1277).

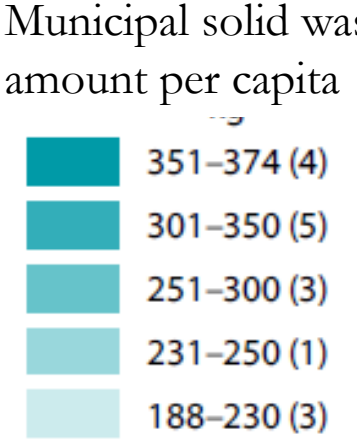
APPLIES

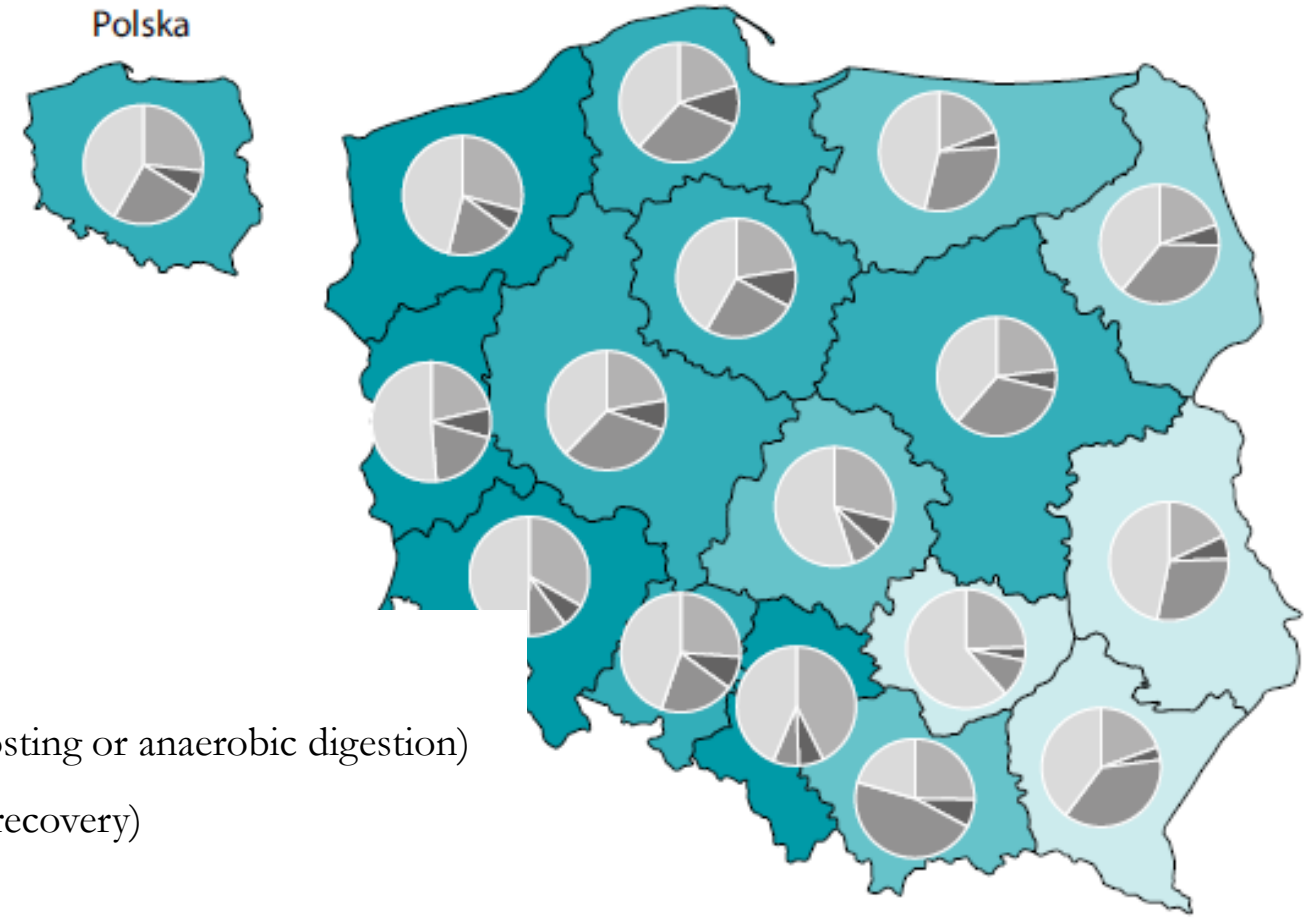
Grup 19) waste from installations and facilities for waste management, Sewage treatment plants and drinking water treatment and water treatment for industrial use (waste: **19 08 05, 19 08 12, 19 08 14, 19 12 12)**

Grup 20) municipal wastes including separately collected fractions.

Municipal solid waste managment in 2017

Municipal solid waste - amount per capita





Treatment method

- Recycling
- Organic recycling (composting or anaerobic digestion)
- Thermal proces (Energy recovery)
- Landfilling

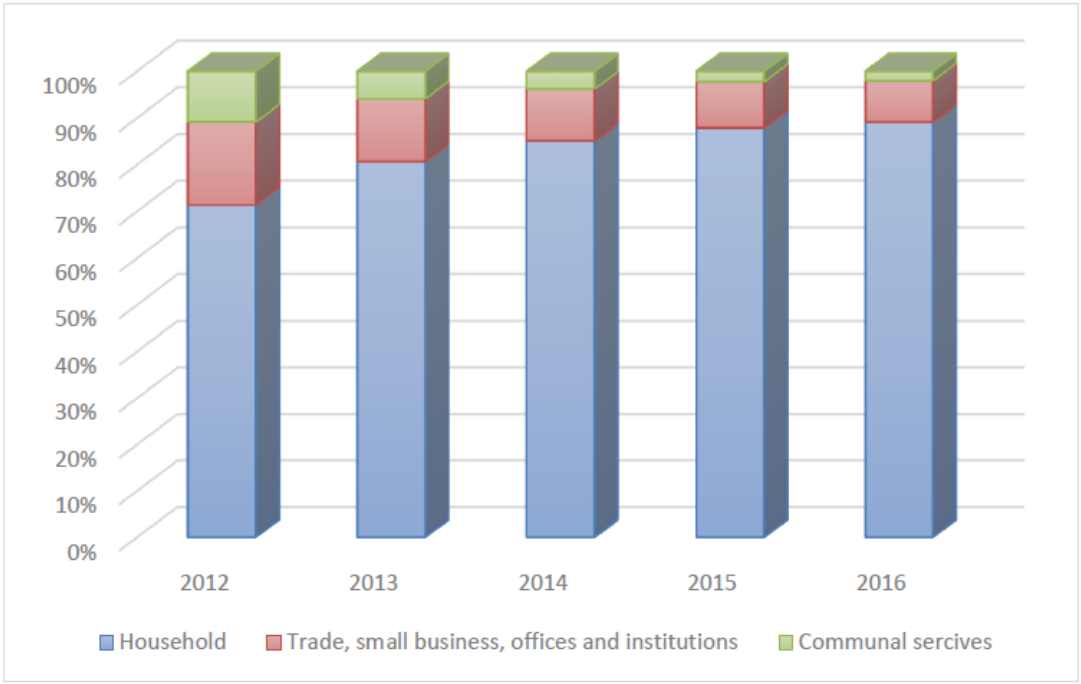
Source: GUS, Municipal infrastructure in 2017

Fraction of selectively collected municipal waste – kg per capita

Zebrane lub odebrane selektywnie odpady na 1 mieszkańca (kg)	2005	2010	2015	2016	2017
Total	7,7	22,3	66,0	76,6	84,3
Paper	2,5	4,4	6,3	6,6	6,0
Glass	2,6	5,6	11,0	11,6	12,1
Plastic	1,1	3,2	7,9	7,9	7,7
Mixed packing waste	.	.	10,9	13,3	14,3
Bulk waste	0,9	2,7	6,8	8,8	11,5
Biodegradable	.	4,7	17,1	21,4	23,3

Source: GUS, Municipal infrastructure in 2017

Sources of waste collected selectively in Poland



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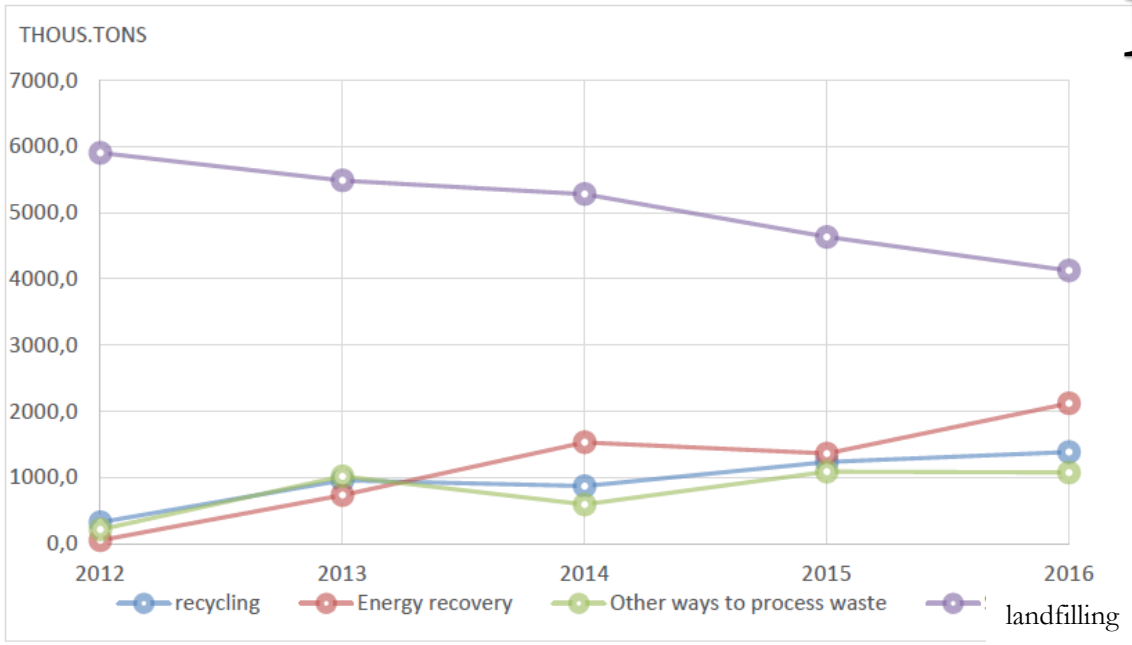
Managament of mixed waste (A) and selectively collected municipal waste (B) in Poland

A



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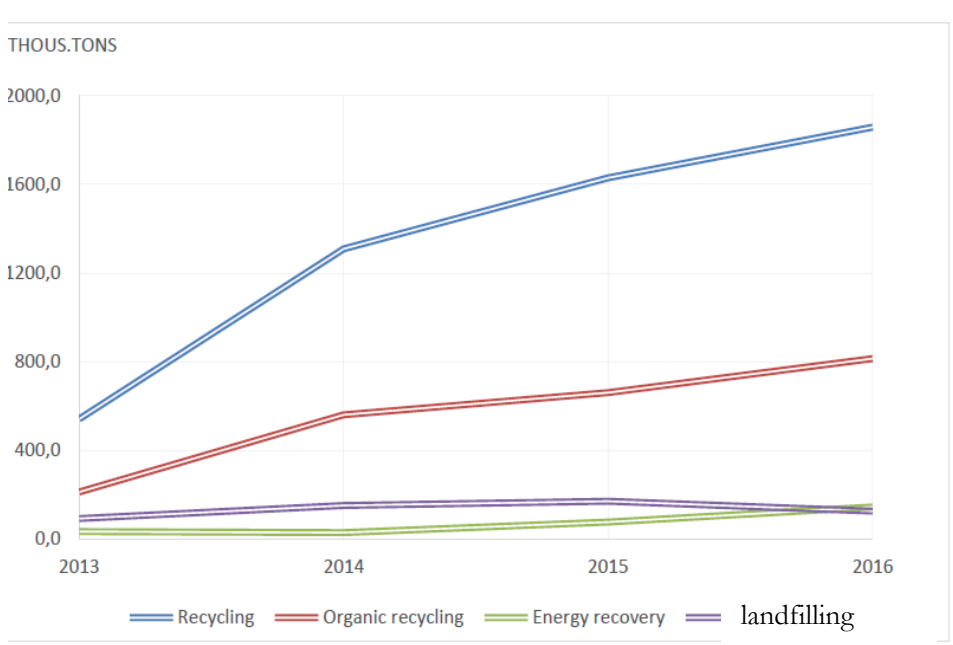

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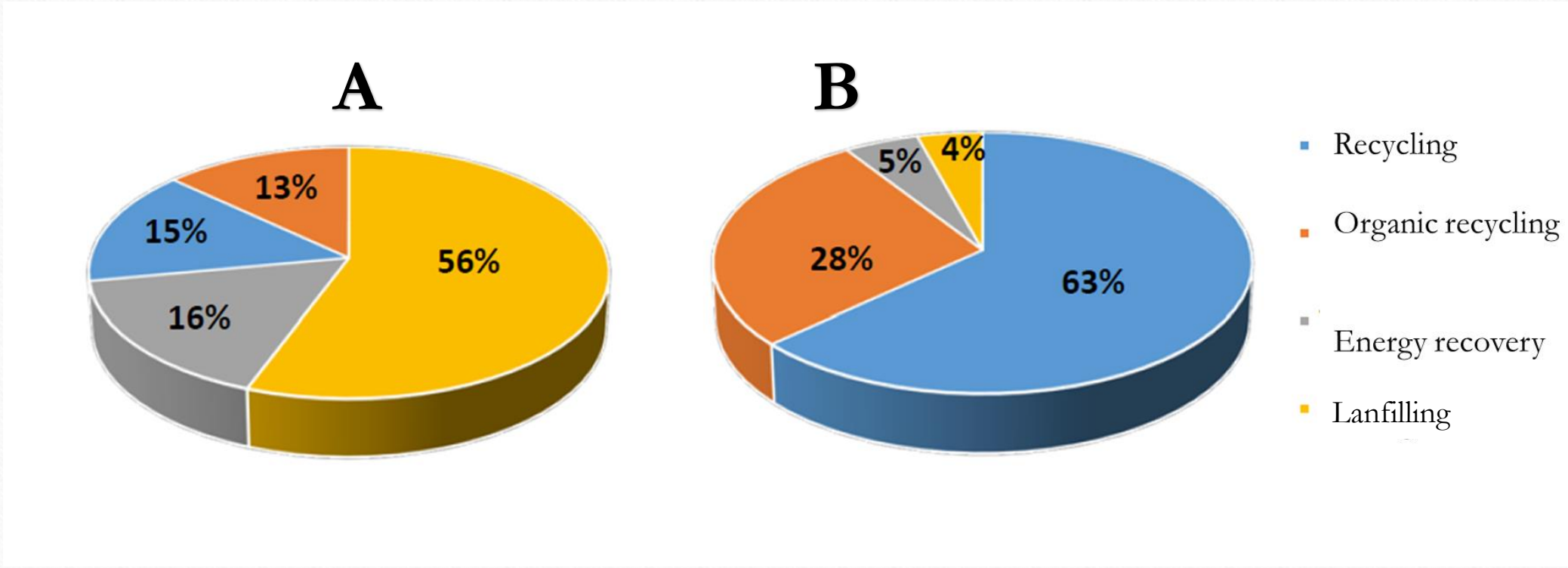

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MBP installation in Poland in 2016

Installations for the processing of green waste and bio-waste in 2016

Source: https://www.teraz-srodowisko.pl/media/infografiki/4292/?mobile

Number of waste incineration plants in Poland in 2016

data from 2019

Lp.	voivodeship	Name	capacity (Mg/a)
1	Wielkopolskie	Miejski Zakład Gospodarki Odpadami Komunalnymi Sp. z o.o.	94 000
2	Wielkopolskie	Miasto Poznań	210 000
3	Podlaskie	Przedsiębiorstwo Usługowo-Handlowo-Produkcyjne "LECH" Spółka z o.o.	120 000*
4	Kujawsko-pomorskie	Międzygminny Kompleks Unieszkodliwiania Odpadów ProNatura Sp. z o.o.	180 000
5	Małopolskie	Krakowski Holding Komunalny S.A.	220 000
6	Zachodniopomorskie	Zakład Unieszkodliwiania Odpadów Spółka z o.o.	150 000
7	Mazowieckie	Miejskie Przedsiębiorstwo Oczyszczania w m. st. Warszawie Sp. z o. o.	60 000
8	Podkarpackie	Instalacja Termicznego Przetwarzania z Odzyskiem Energii (ITPOE) PGE GiEK SA Oddział Elektrociepłownia Rzeszów – I etap	100 000

Source: https://www.teraz-srodowisko.pl/media/infografiki/4292/?mobile; Ministerstwo Środowiska Informacja na temat spalarni odpadów komunalnych i ich miejsc w systemie gospodarki odpadami, 2019

Biodegradable waste other than municipal waste acording to National Waste Management Plan 2022

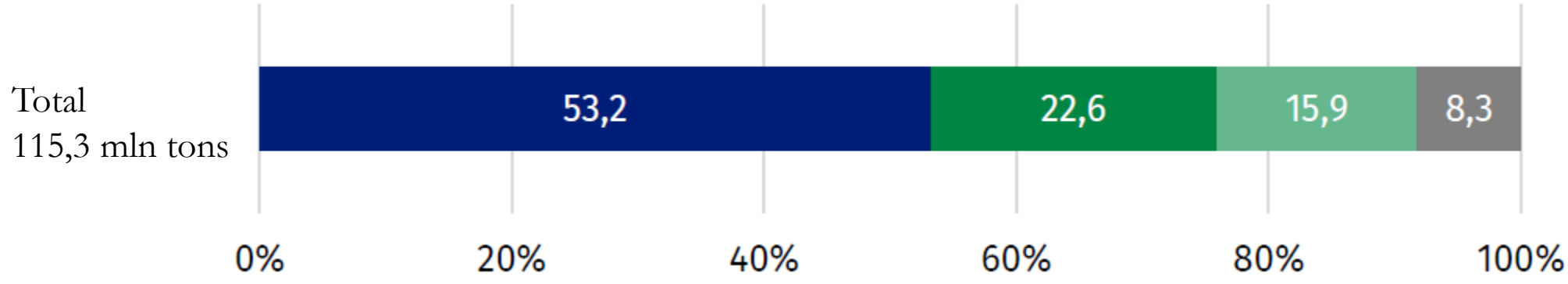
Grup 2) waste from agriculture, horticulture, aquaculture, forestry, hunting and food processing,

Grup 3) waste from wood processing and the production of panels and furniture, pulp, paper and paperboard,

Grup 19) waste from installations and facilities for waste management, Sewage treatment plants and drinking water treatment and water treatment for industrial use,

Out of the entire weight of generated waste, 97.3% are recovered, 1.6% are disposed and 1.1% are landfilled

Industrial waste



- Mining and quarrying
- Industrial processing
- Production and supply of electricity, gas, steam and hot water
- Other sections

Recycling (50.7%)
Storage (42.5%).

Source: GUS, Environmental Protection in 2018.

Biodegradable waste definitions

- (Polish) Act of 14 December 2012 on waste specifies:
- - biodegradable waste - it means
- wastes that are aerobically degradable or anaerobic with the participation of microorganisms

Biodegradable waste management in Poland

- Processing is prohibited:
- mixed municipal waste, residues from sorting municipal waste, if they are intended for storage, green waste
- - outside the municipal waste management region in which they were produced.
- It is forbidden to import waste generated outside the region into the municipal waste management region.

Biodegradable waste management in Poland

- It is forbidden to:
- the use of municipal sewage sludge, disposal of infectious medical waste and infectious veterinary waste
- - outside the voivodship in which they were produced
- Municipal sewage sludge may be used in an area of a voivodship other than the one in which it was generated, if the distance from the place of waste production to the place of use located in the area of another voivodship is smaller than the distance to the place of use located in the area of the same voivodship.

The main tasks of the communes:

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Imposition of obligations at EU level (Directive on the landfill of waste) to limit the mass of biodegradable municipal waste destined for storage by selective collection

- Poland has been obliged to reach the following levels recovery:
- until 2010, up to a maximum of 75% by weight of the total weight biodegradable municipal waste
- until 2013, not more than 50% by weight of the total weight biodegradable municipal waste
- by 2020, up to a maximum of 35% by weight of the total weight biodegradable municipal waste
- in relation to the mass of this waste generated in 1995.

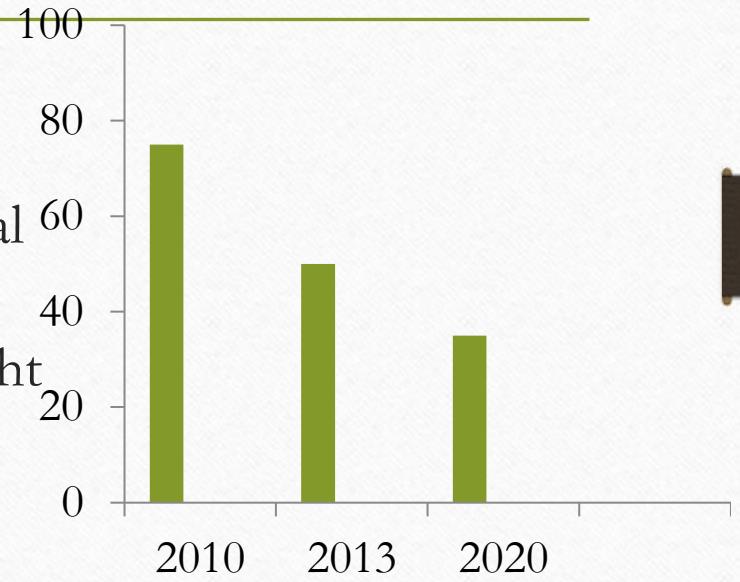


Table 1. Average cost of different strategies of management of sewage sludge in European countries [15].

Methods of utilization	Cost (EURO)/t DM)
Agriculture; Raw sludge; Partly dewatered sludge (15–25% DS)	160
Dry sludge	210
Forestry	240
Composting	310
Incineration	315
Reclamation of landfills and degraded areas; Landfill	255

- T Turlej, M BanaśSustainable management of sewage sludge,, E3S Web of Conferences 49, 00120 (2018) https://doi.org/10.1051/e3sconf/20184900120, SOLINA 2018,

Table 1

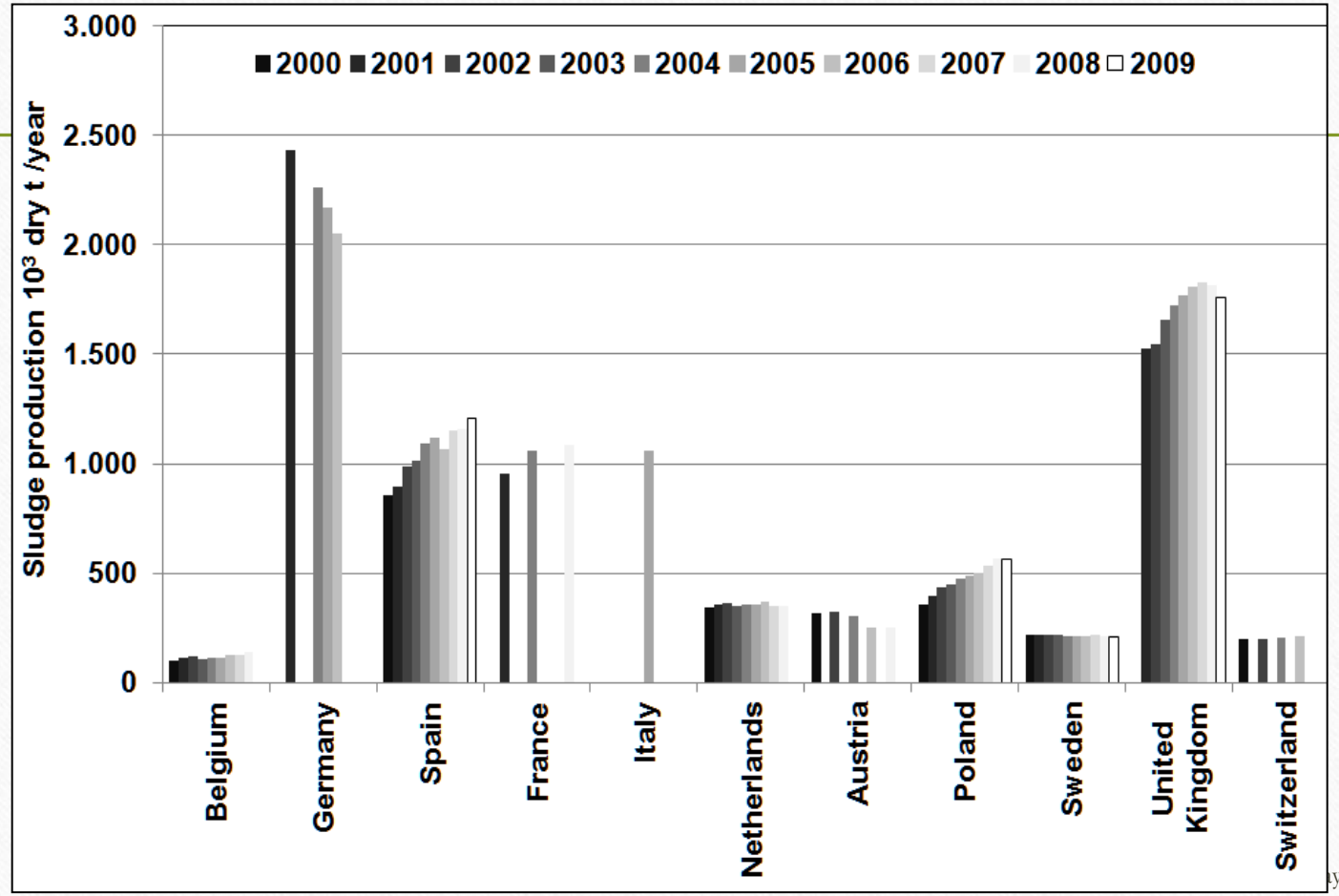
Sewage sludge (SS) management in Poland for 2016 (Statistical Yearbook of the Regions)

Sewage sludge (SS) utilization	Total SS (industrial and municipal), tonnes of dry solid
Land reclamation	31,724
Compost production	32,807
Bulk storage	61,889
Landfilling	97,569
Agriculture	133,887
Thermal conversion	194,677
Other uses	394,638
Accumulated*	6,286,969

*Total annual SS accumulated on the WWTP on landfill areas

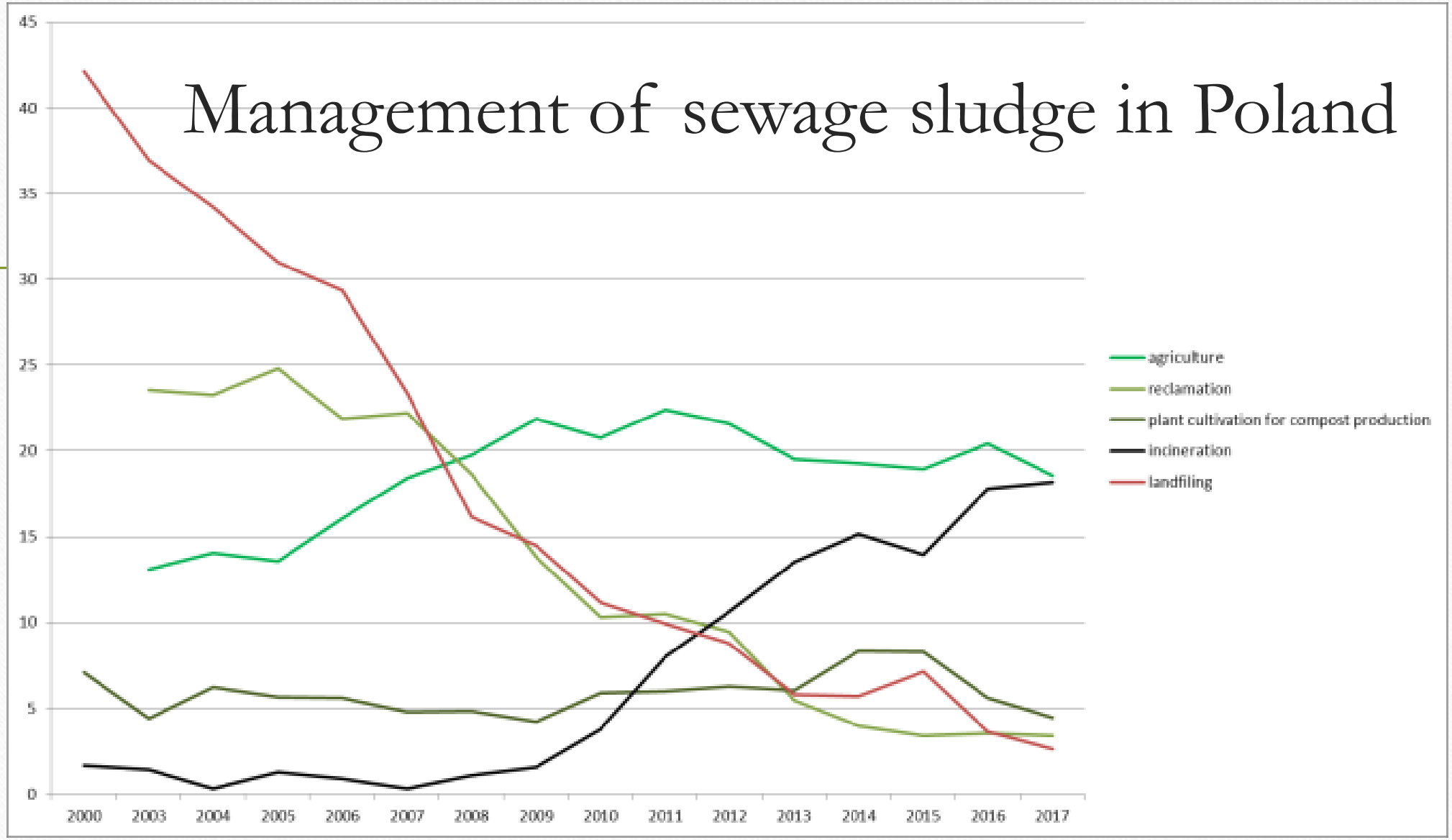
Werle, S. & Sobek, S. Environ Sci Pollut Res (2019). https://doi.org/10.1007/s11356-019-05897-2

The production of sewage sludge in selected countries of EU

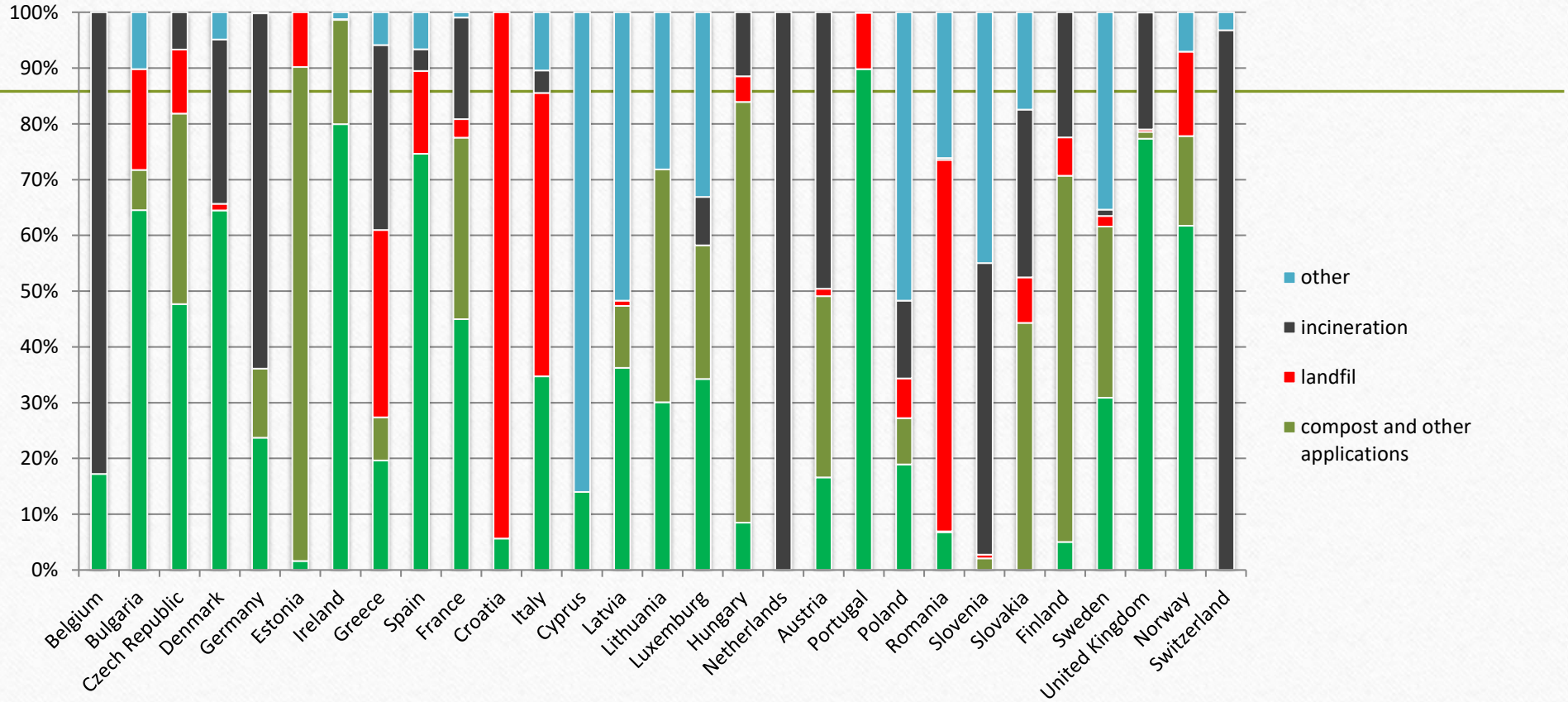


Mininni G., Dentel S. 2013

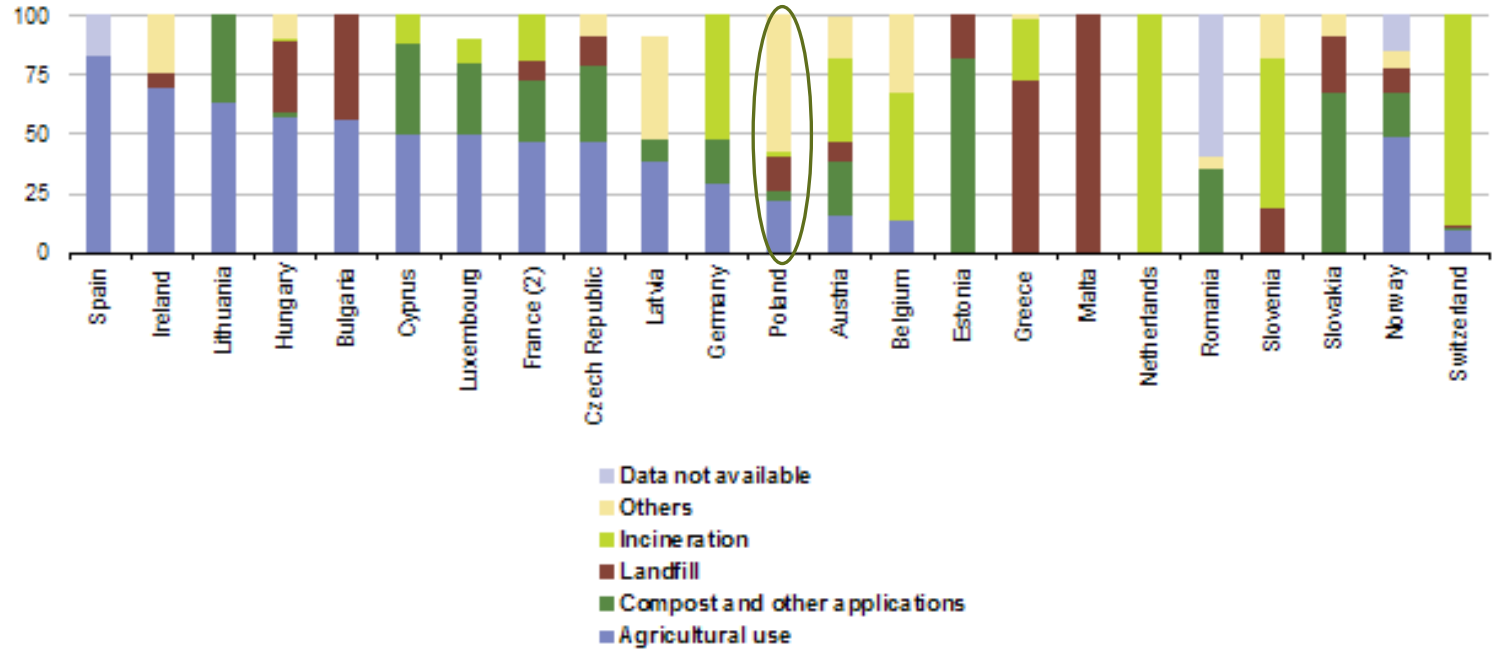
Management of sewage sludge in Poland



Management of sewage sludge in EU countries in 2015



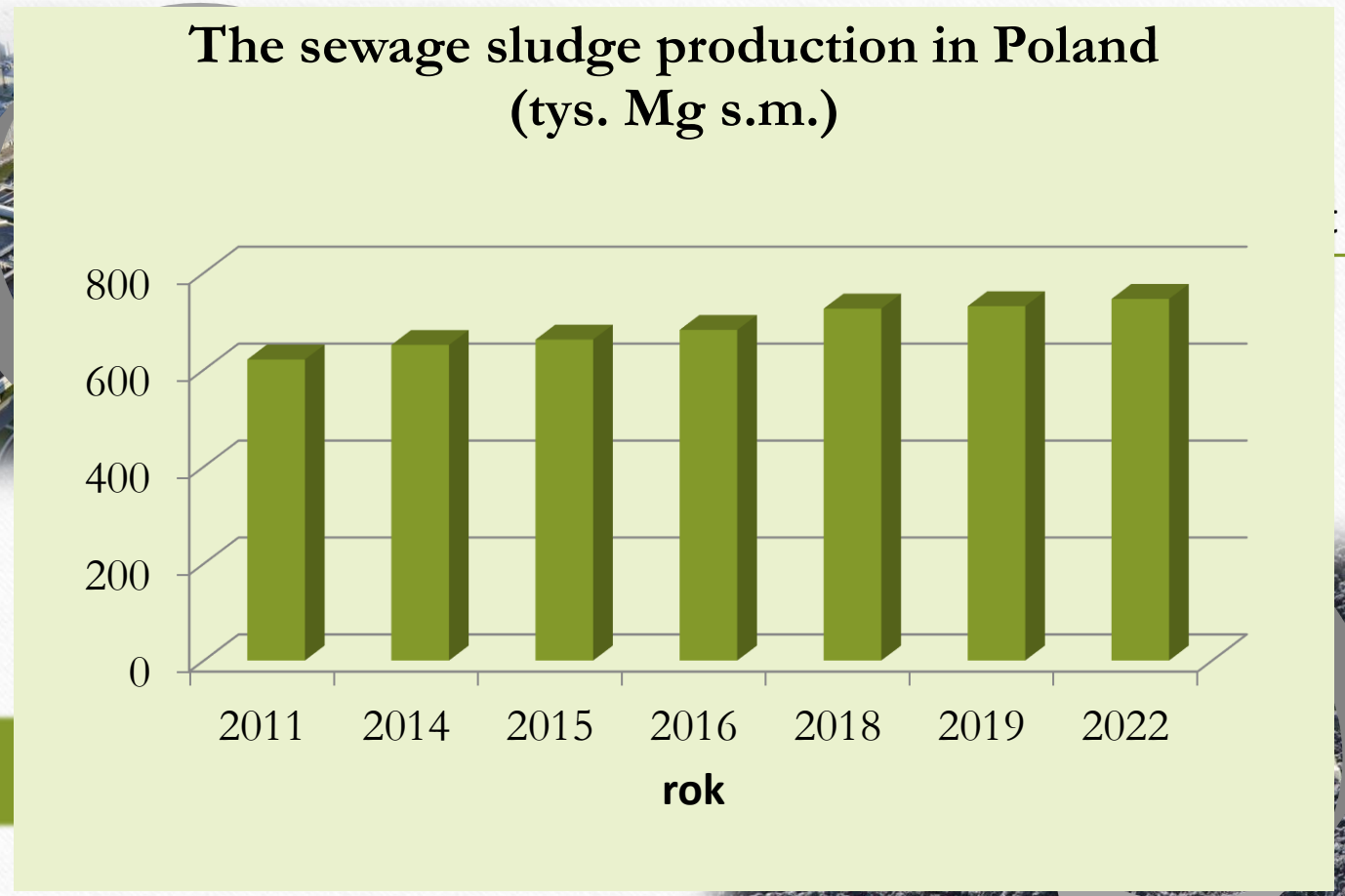
Sewage sludge disposal from urban wastewater treatment, by type of treatment, 2009



(1) Belgium, the Czech Republic, Germany, France, Luxembourg, the Netherlands and Austria, 2008; Ireland, Cyprus, Latvia, Hungary and Slovakia, 2007; Switzerland, 2006; Denmark, Italy, Portugal, Finland, Sweden and the United Kingdom, not available.

(2) Based on a total excluding the category of other types of treatment.

Source: Eurostat (online data code: env_watq6)


The sewage sludge production in Poland
(tys. Mg s.m.)
800
600
400
200
0
2011
2014
2015
2016
2018
2019
2022
rok

EU REGULATION

- Council Directive 91/271/EEC of 21 May 1991 concerning urban wastewater treatment
- **Council Directive 86/278/EEC of 12 June 1986 on the protection of the environment, particularly the soil, when sewage sludge is used in agriculture**.
- Directive 1999/31/EC on the landfill of waste
- Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control)

- Was

Or

???

- Substrate

Sewage sludge – a sink for pollutants or for nutrients?

- Sewage sludge can contain all heavy metals and organic pollutants we use in daily life.

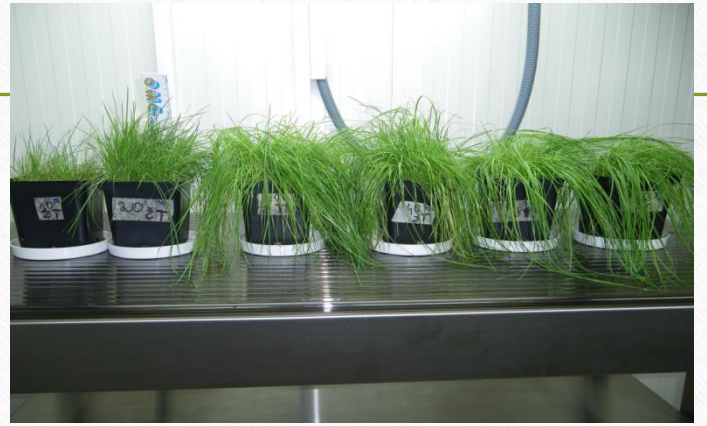
but

- Sewage sludge also has many nutrients, among others nitrogen and phosphate

Parameter	unit	value	Parame-ter	unit	value
Dry matter	%	12.5-39.1	Cd	mg kg^{-1} d.m.	0.2-56.2
pH	-	5.6-12.6	Cr	mg kg^{-1} d.m.	3.2-8500
Matter org.	% d.m.	8.70-85	Cu	mg kg^{-1} d.m.	3.0-1840
C org.	% d.m.	21-63.3	Hg	mg kg^{-1} d.m.	0.003-7.55
C : N	-	5-22	Mn	mg kg^{-1} d.m.	20-1465
N	% d.m	0.125-8.35	Ni	mg kg^{-1} d.m.	1.7-911
P	g kg^{-1} d.m.	0.4-36.1	Pb	mg kg^{-1} d.m.	5.0-2970
K	g kg^{-1} d.m.	0.2-5.7	Zn	mg kg^{-1} d.m.	126-4640
Ca	g kg^{-1} d.m.	0.8-115	Fe	g kg^{-1} d.m.	8.0-71
Mg	g kg^{-1} d.m.	0.2-12.6			
S	g kg^{-1} d.m.	6.3-8.0			

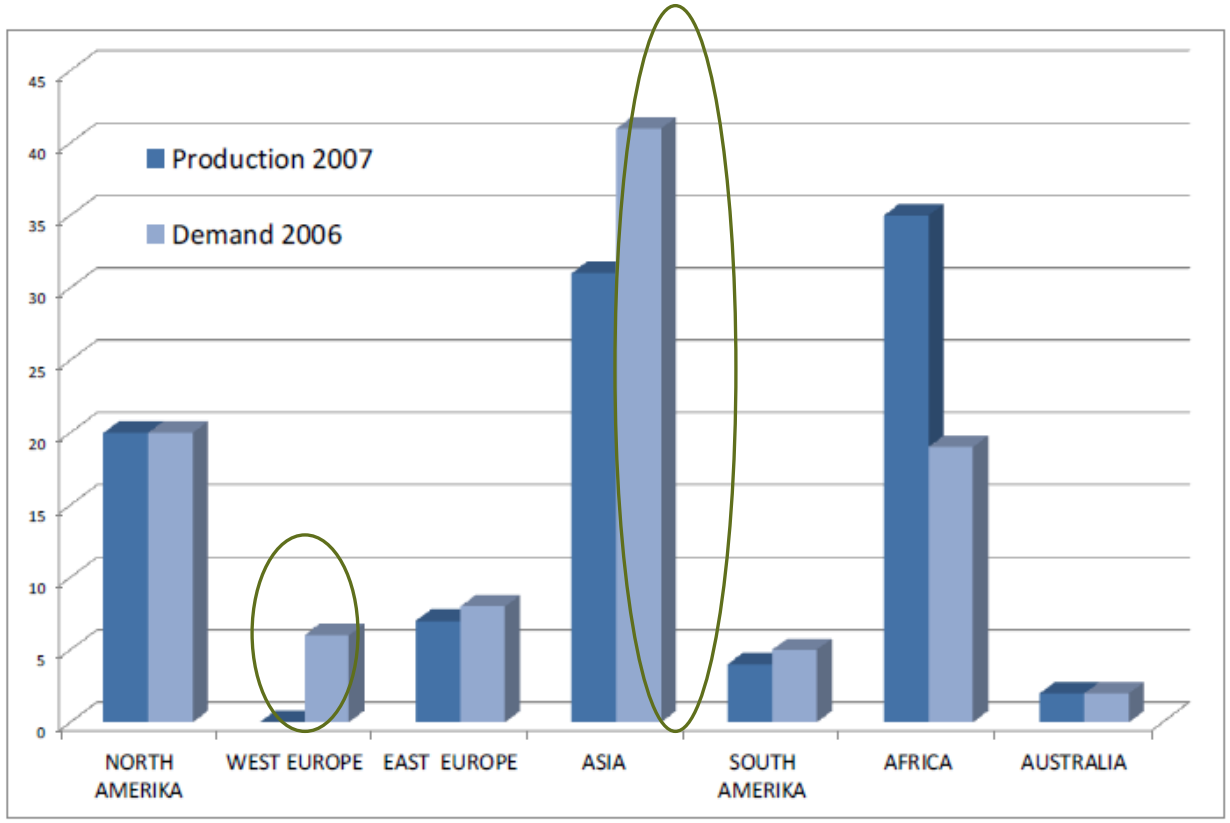
Sewage sludge as a resource

- Recycling
- Sustainability
- Protection of resources
- Resource efficiency



- Phosphate resources world wide: 80 -110 years
- In future recovery of phosphate from waste water and sewage sludge may be established
- To date agricultural use of sewage sludge remains good practice

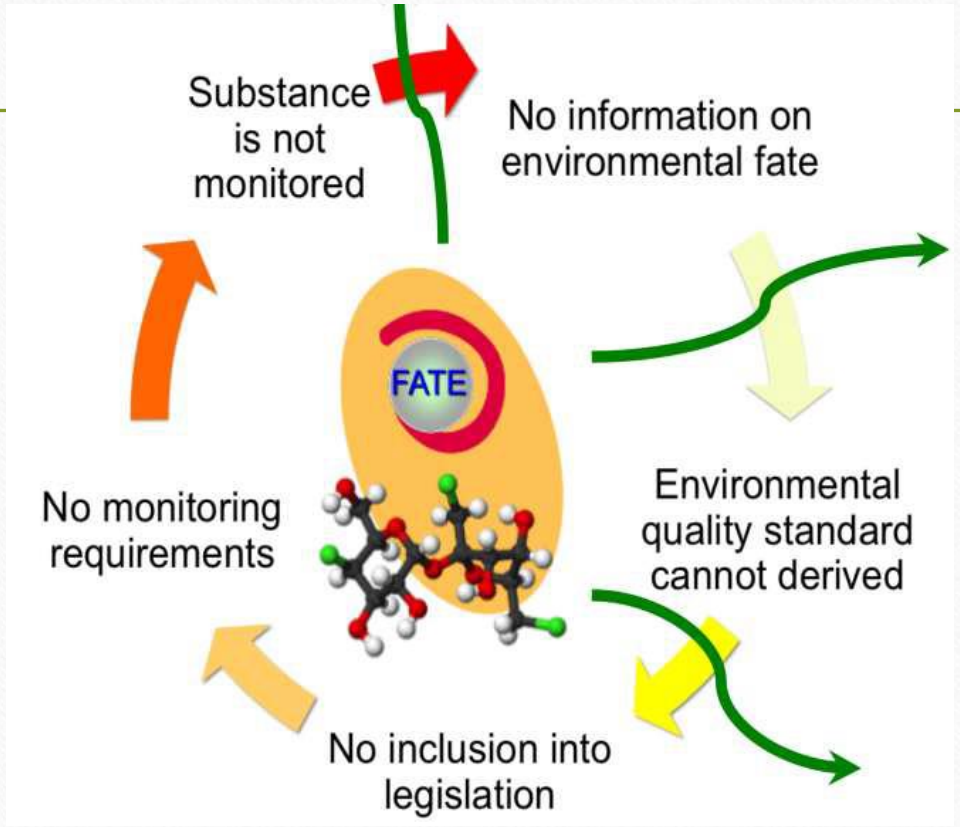
Phosphate world wide



Source: BGR, Hannover

Sewage sludge as a pollutant

- **Heavy metals**
- **PAH**
- **PCB**
- **Perfluorinated Surfactants (PFCs)**
- **Polycyclic Musks**
- **Siloxanes**
- **Pesticides**
- **Phenols**
- **Sweeteners**
- **Personal Care Products**
- **Pharmaceuticals**
- **Benzotriazoles**

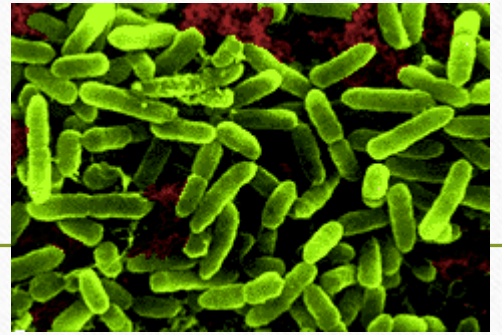


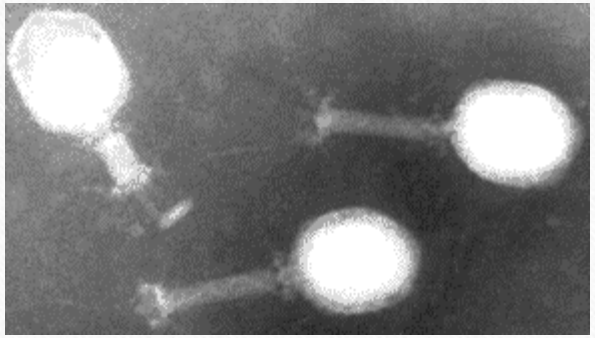
Screening 1

(ng/g)	Average	Median	Min	Max	N	Positive detection	in %
2,4-Dinitrophenol	0.9	0.5	0.1	4.0	58	38	65.5
Acesulfame K	14.7	4.6	0.1	156.7	58	53	91.4
Acetylsalicylic acid	63.9	32.0	0.6	563.0	58	57	98.3
Bezafibrate	0.7	0.2	0.0	6.8	58	41	70.7
Chloramphenicol	1.7	0.3	0.0	7.6	58	5	8.6
Clofibric acid	1.7	1.0	0.1	10.5	58	17	29.3
Dichlorprop	0.1	0.1	0.0	0.5	58	9	15.5
Diclofenac	43.6	29.2	1.3	429.1	58	47	81.0
Gemfibrozil	2.9	1.8	0.3	9.4	58	6	10.3
Ibuprofen	18.2	10.8	0.2	108.2	58	42	72.4
Imidacloprid	0.8	0.8	0.8	0.8	58	1	1.7
Ketoprofen	2.6	1.1	0.3	8.6	58	8	13.8
MCPA	0.9	0.3	0.3	2.2	58	3	5.2
Mecoprop	0.8	0.8	0.4	1.2	58	2	3.4
Naproxen	2.6	1.4	0.2	9.0	58	34	58.6
Nitrophenol	3.7	2.1	0.2	22.2	58	50	86.2
PFDA	10.7	5.2	0.0	69.2	58	33	56.9
PFHpA	1.9	0.5	0.1	23.3	58	46	79.3
Saccharin	8.9	3.5	0.6	72.8	58	37	63.8
Sucralose	2.0	0.8	0.0	19.2	58	36	62.1

Microbes occuring in sewage sludge

Viruses	Bacteria	Fungi	Protoza	helmintes
Wirus Polio	*Arizona hinshawii*	*Absidia* spp.	*Acanthomoeba*	*Ankylostoma duodenale*
Wirus Coxsackie	*Aeromonas* spp	*Aspergillus fumigatus*	*Dientamoeba*	*Ascaris lumbricoides*
- Echowirus	*Bacillus cereus*	*Candida albicans*	*fragilis*	*Echinococcus granulosus*
Wirus grypy	*Bacillus anthracis*	*Candida guillermondii*	*Entamoeba*	*Echinococcus multilocularis*
Adenowirus	*Brucella* spp	*Candida krusei*	*hystolitica*	*Enterobium vermicularis*
Astrowirus	*Campylobacter jejuni*	*Candida tropicalis*	*Giardia lamblia*	*Hymenolepsis nana*
Caliciwirus	*Citrobacter* spp	*Cryptococcus neoformans*	*Giardia intestinalis*	*Necator americanus*
Coronawirus	*Clostridium botulinum*	*Epidermophyton* spp	*Isospora belli*	*Strongyloides stercoralis*
Enterowirus	*Clostridium perfringens*	*Fusarium* spp.	*Naeglaria fomleri*	*Taenia saginata*
Parowirus	*Enterobacteriaceae*	*Geotrichum candidum*	*Palantidium coli*	*Taenia solium*
Reowirus	*Escherichia coli*	*Microsporum* spp.	*Sarcocystis* spp	*Toxocara cati*
Rotawirus	*Klebsiella* spp	*Mucor* spp.	*Toxoplasma gondii*	*Toxocara canis*
Wirus Norwalk	*Leptospira*	*Penicillium* spp.		*Trichuris trichura*
Hepatitis A wirus	*icterohaemorrhagiae*	*Phialophora richardsii*		
Hepatitis E wirus	*Listeria monocytogenes*	*Trichoderma* spp.		
	Mycobacterium tuberculosis	*Trichosporon cutaneum*		
	Pasteurella pseudotuberculosis	*Trichophyton* spp.		
	Proteus spp	*Verticillium* spp.		
	Providencia spp			
	Pseudomonas aeruginosa			
	Salmonella spp			
	Serratia spp			
	Shigella spp			
	Staphylococcus aureus			
	Enterococcus spp			
	Vibrio parahaemoliticus			
	Vibrio cholerae			
	Yersinia enterocolitica			





Social acceptance of use the sewage sludge in the agriculture

- **the problem of food contamination**
- **health problems**

Land Application of Treated Sewage Sludge: Community Health and Environmental Justice

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Table 1. Acute (short duration) physical symptoms respondents attributed to sludge exposure (n = 18/34 respondents).

Acute symptom	No. of respondents reporting symptom
Eye, nose, throat irritation	8
Nausea, vomiting, diarrhea	8
Cough	5
Difficulty breathing	4
Sinus congestion, drainage	4
Skin infection, irritation, sore	2

Table 2. Activities respondents said they are unable to do because of malodor from sludge during and for up to several months after a sludge application event (n = 22/34 respondents).

Activity	No. of respondents reporting activity limitation
Let children play outdoors	8
Open house/car windows	8
Host relatives or outdoor social gatherings	6
Line-dry laundry	5
Walk freely around the neighborhood	5
Garden or work outside	4
Sit outside as a family	3
Stay home	3

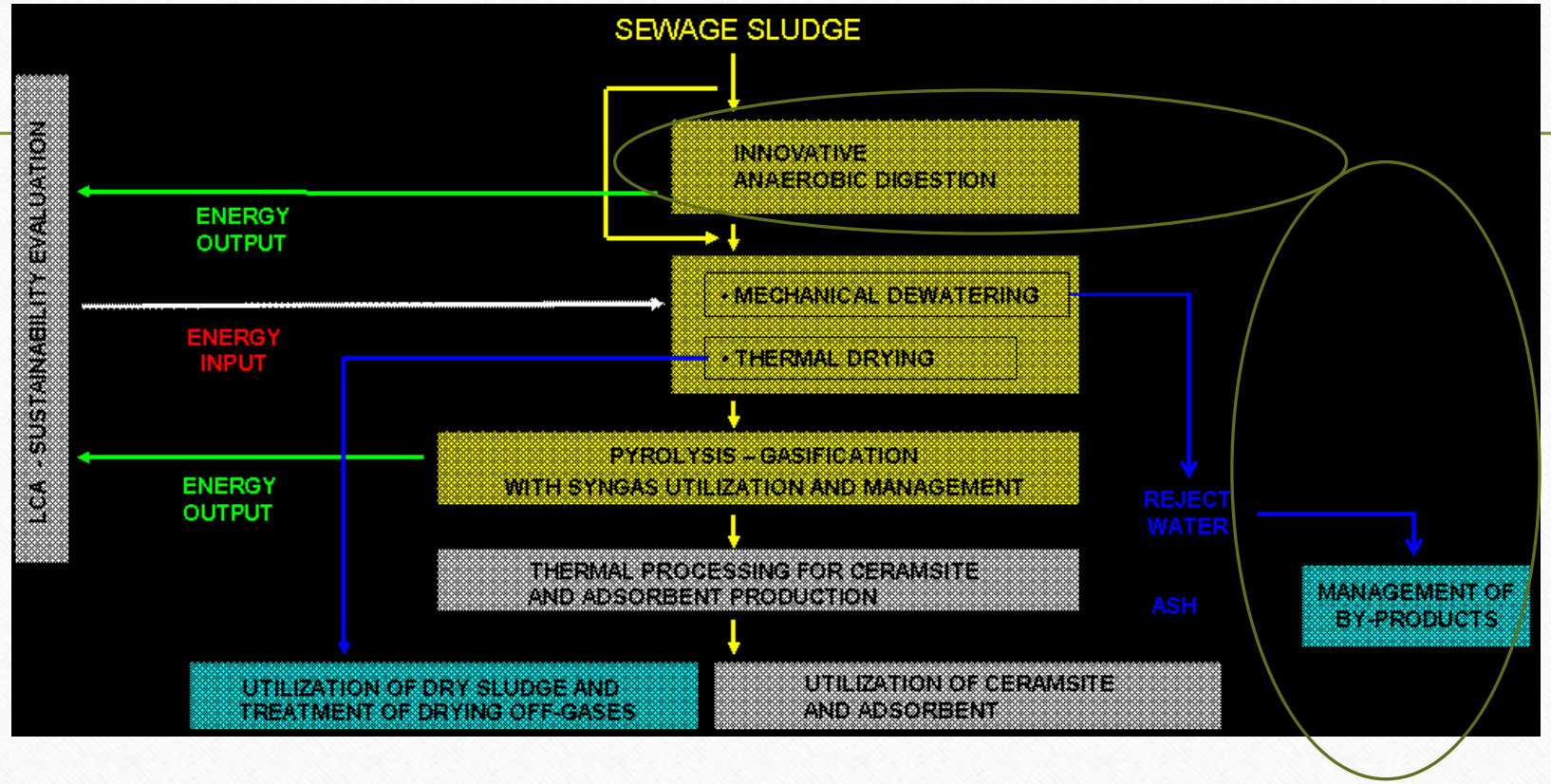
Table 3. Number of respondents reporting observations of environmental concern (n = 18/34 respondents) regarding land application operations.

Reported observation	No. of respondents reporting observation
Sludge spillage on road, path, or property	9
Cattle grazing < 30 days after an application event	7
No signage marking application sites during and after application events	6
Sludge runoff into surface waters	5
Sludge in buffer zones (e.g., across property lines, near ditches, gardens, and private wells)	4
Failure of sludge to assimilate into soil	3
Unmarked application boundaries	2
Application during rain event	2
Application in critical watershed	1

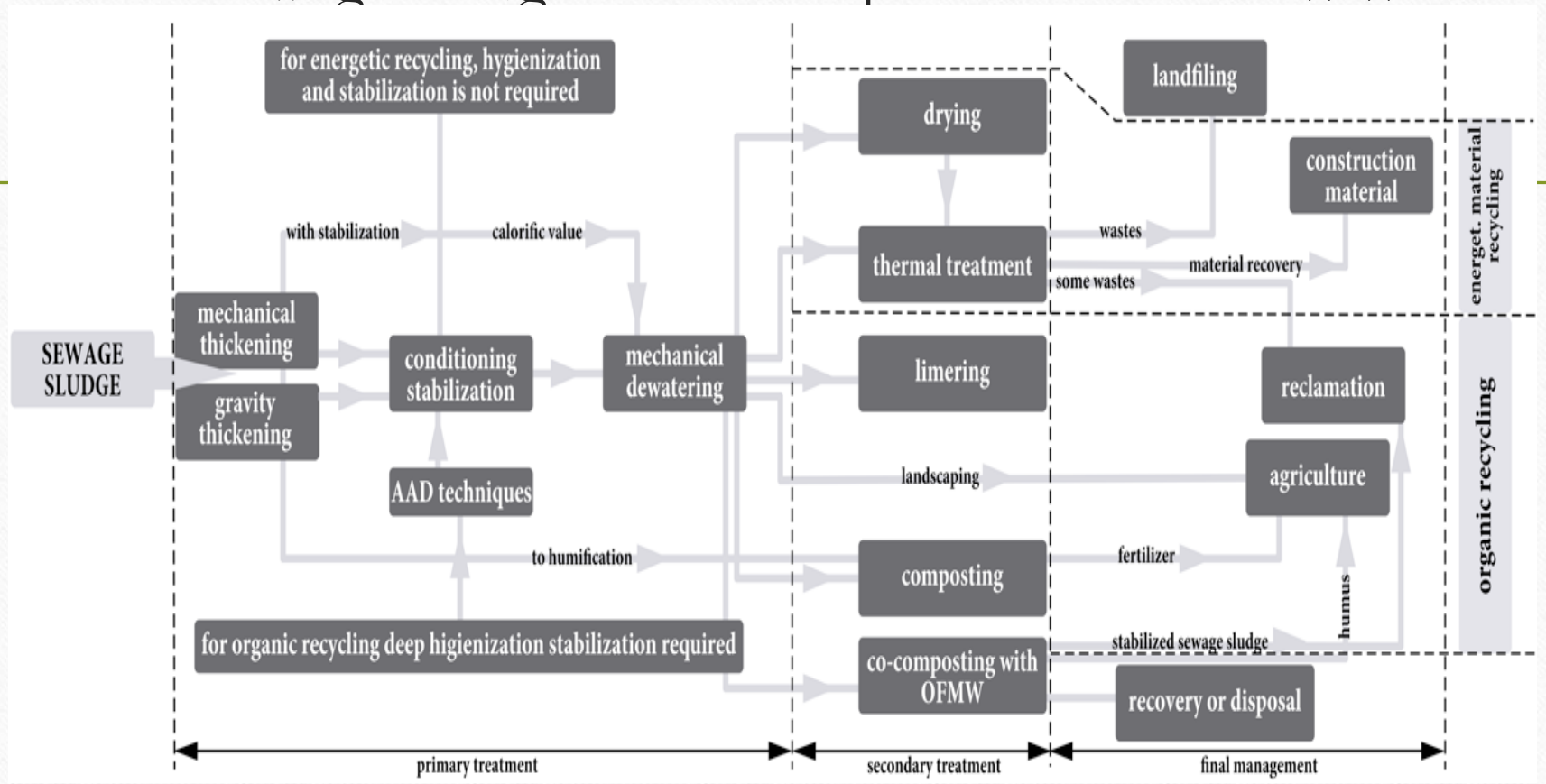
integrated system for a sustainable management of sludge

Many countries (like Norway) recognized that sludge and sludge components may be recycled in **a "productification" strategy**, i.e. a strategy aimed at making products from sludge intended for sale in the market place. This strategy includes two principal trends. The first is the production of specific products that can be recycled, like heat, electricity made from biogas etc. The other trend is to go for "bio-soils", i.e. soil products with treated sludge as a central ingredient.

Spinosa et al. 2011

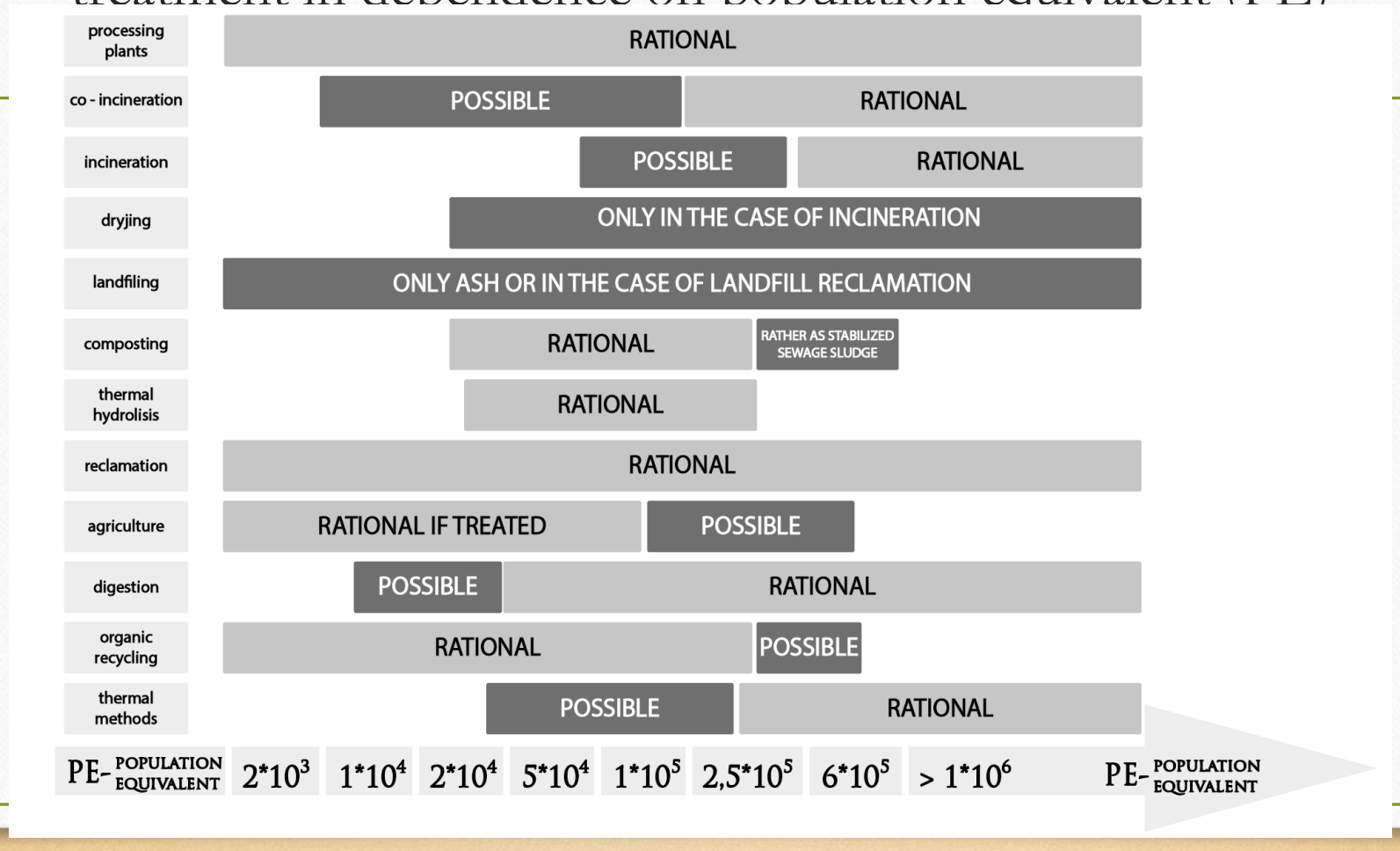


The sewage sludge treatment processes at the WWTP

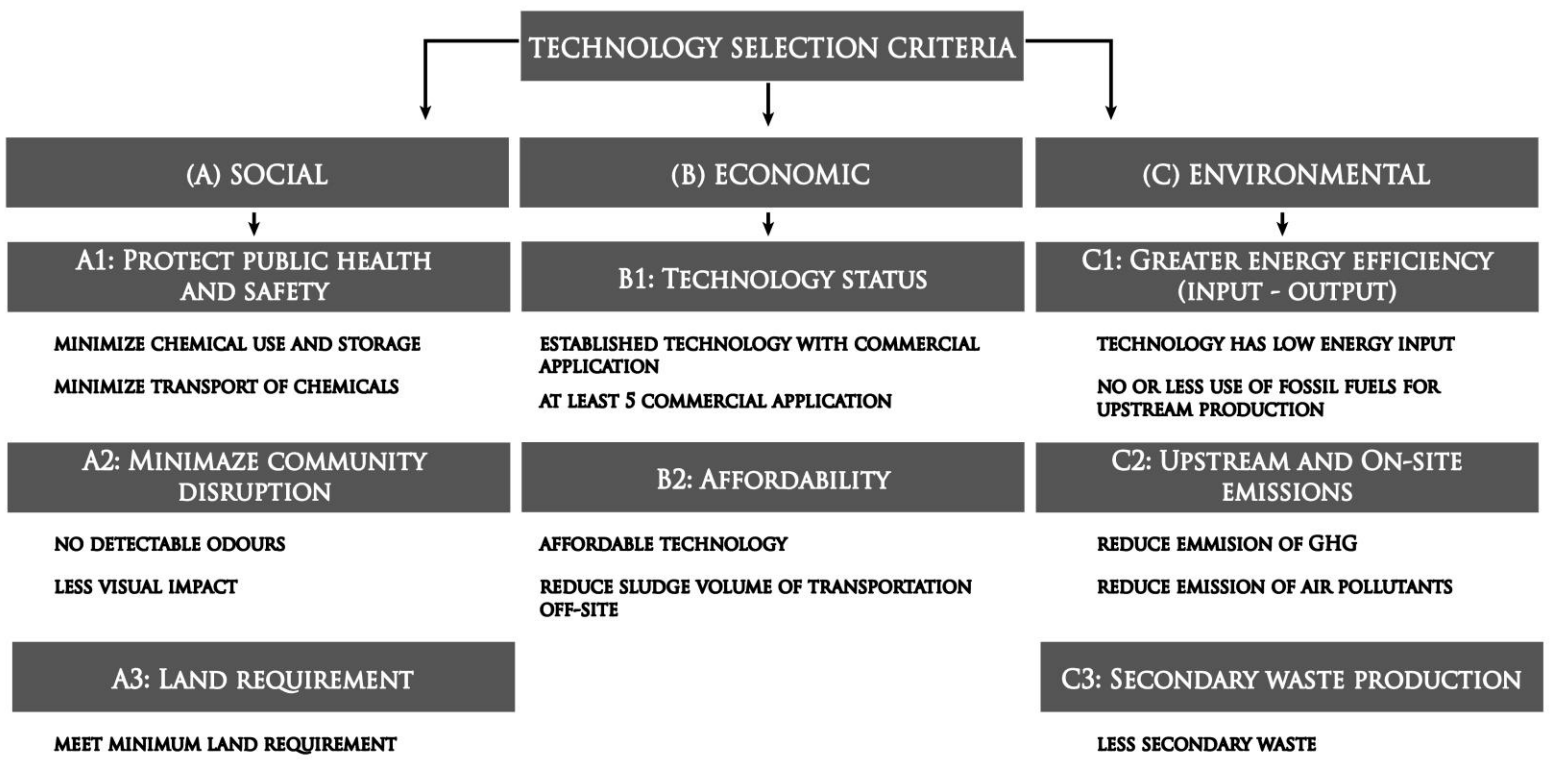


Wojtowicz et al. 2013

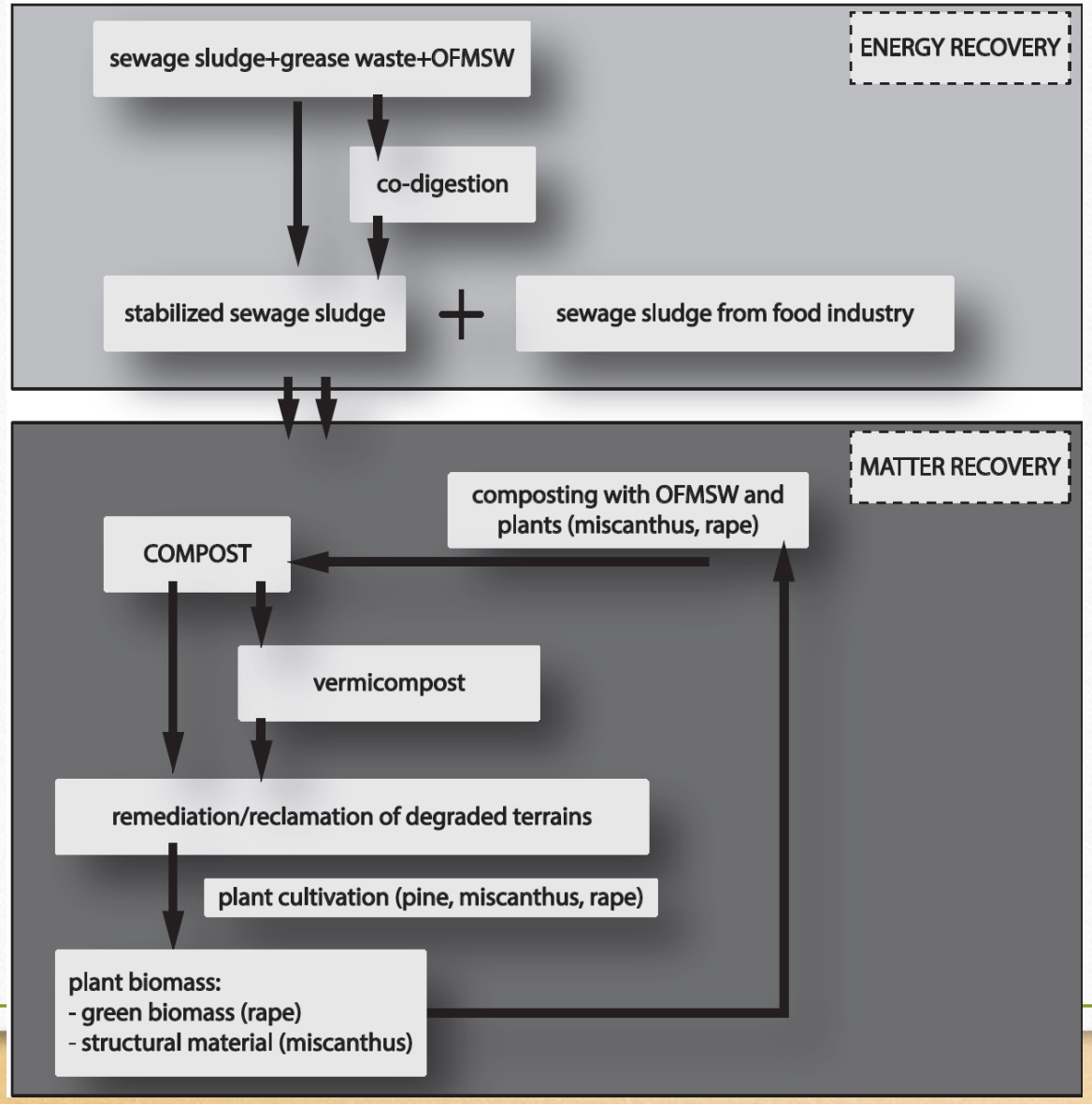
Main recommendations of selected processes of sewage sludge treatment in dependence on population equivalent (PE)



Social, economic and environmental criteria for related to technology development for resource recovery from waste sludge



Tyagi, V. K., & Lo, S. L. (2013). Sludge: A waste or renewable source for energy and resources recovery?. Renewable and Sustainable Energy Reviews, 25, 708-728.



The possible scenario of sewage sludge management with implementation of circular economy

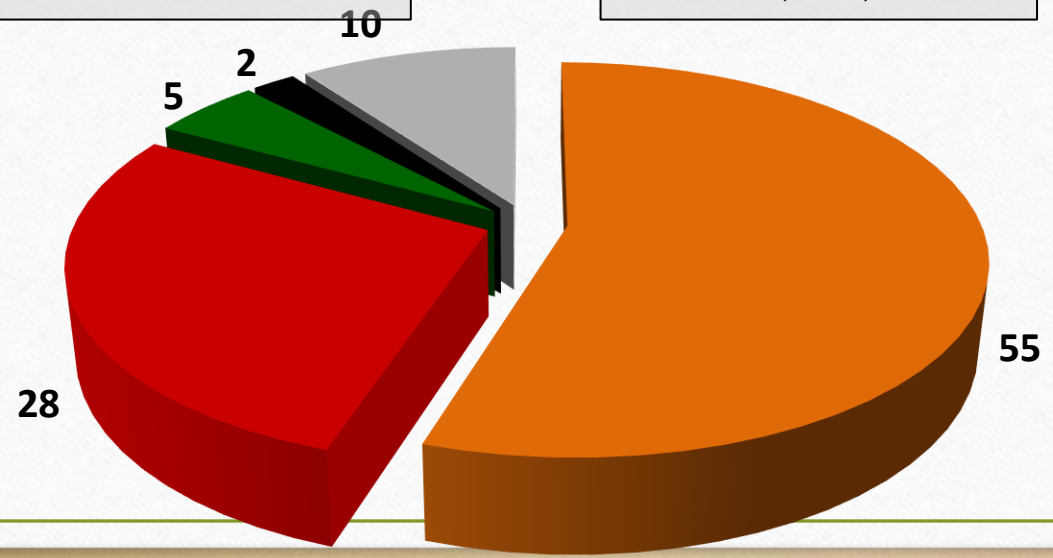
BIOTENAMARE PROJECT
POLISH-NORWEGIAN PROGRAMME

Improving of anaerobic digestion and bioenergy production

Sewage sludge (SS) and inoculum

Grease trap sludge (GTS)

Organic fraction of municipal solid wastes (OFMSW)



Synthetic OFMSW

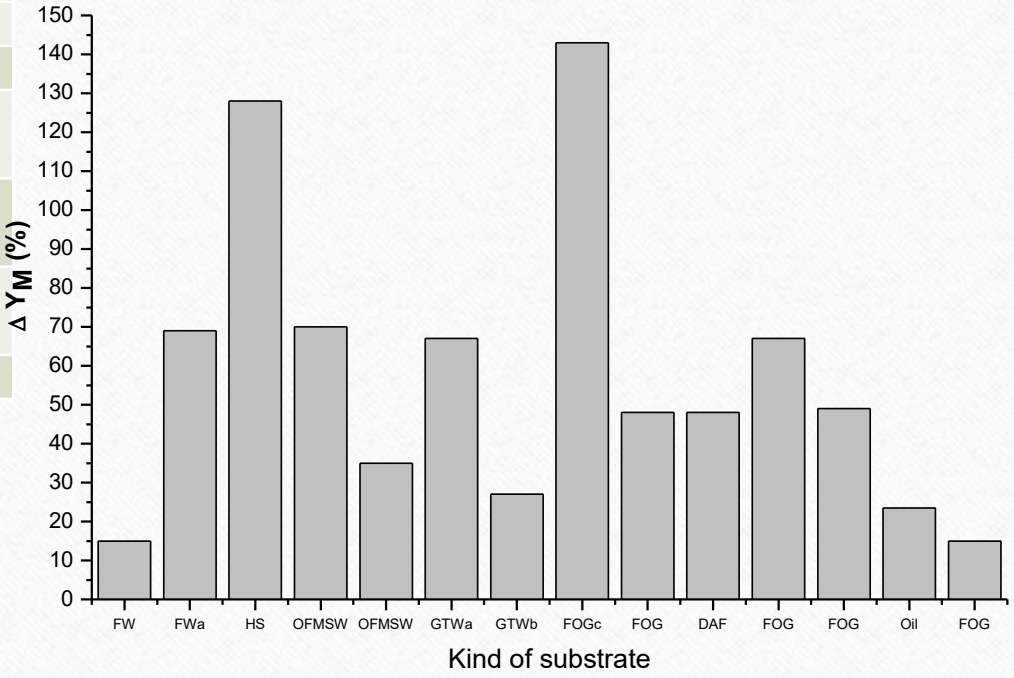
- potato
- fruits and vegetables
- bread
- paper
- rice, pasta and buckwheat groats

Sosnowski, P., Klepacz-Smolka, A., Kaczorek, K., Ledakowicz, S., (2008), Kinetic investigations of methane co-fermentation of sewage sludge and organic fraction of municipal solid wastes, Bioresource technology, 99(13), 5731-5737.

Implementations of co-digestion in full scale plants

Kind of co-substrates	Improvment (%)*
grease trap waste	81.9
grease trap waste	50
grease trap waste	32.4
Organic fraction of municipal waste	21
Organic fraction of municipal waste	97
Organic fraction of municipal waste	54
used oil	24

* compared to anaerobic digestion of sewage sludge alone



FW -fruit wastes, **FWa** - food waste, **HS** - organic waste from domestic refuse (swill), **OFMSW** - organic fraction of municipal waste, **GTWa** - grease trap sludge from a meat processing plant , **GTWb** - grease trap sludge from restaurant, **FOG** - gat oil grease, **FOGc** -FOG from FOG receiving facility, **DAF** - greasy sludge from flotation process, **Oil** - oil from restaurant

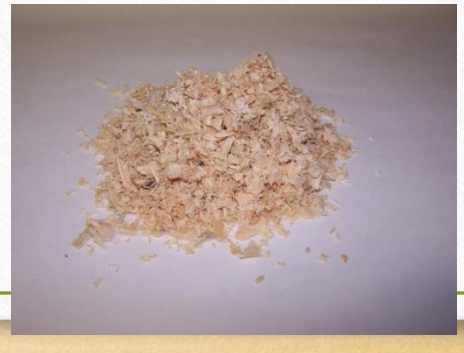
Composting of sewage sludge

Organic fraction of municipal solid waste

Grass

Sewage sludge from meat industry

Bulking agent



vermicomposting

Eisenia andrei

Eisenia fetida

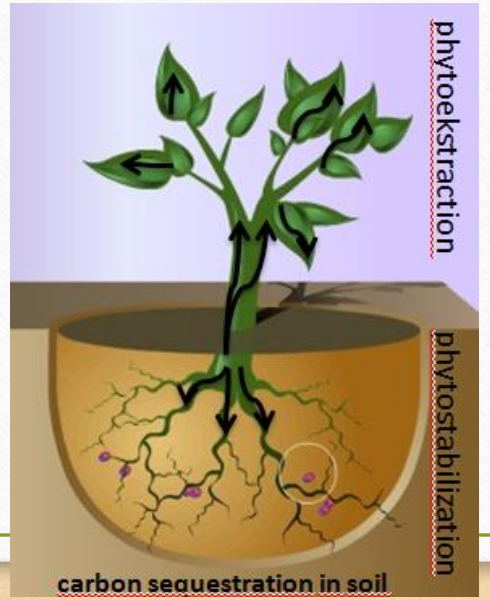
BROWNFIELDS

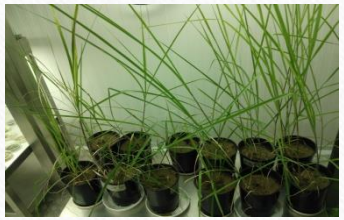
- sands and gravels,
- low humidity,
- low pH,
- deficiency of nutrients,
- large amounts of heavy metals Cd, Pb and Zn in the bioavailable form

- clays, sands and gravels, l
- low humidity,
- neutral or alkaline pH,
- deficiency of nutrients,
- large amount of FeS2,
- no level of humus

IMPROVEMENT OF SOIL QUALITY

sewage sludge from the food industry	compost from the biodegradable fraction of municipal waste	compost from sewage sludge





Miscanthus giganteus

Pine

<u>Puropose of research:</u> to determine the degree of immobilization of pollutants and carbon seqestration in the soil by the different types of organic amendments and plants from forest species (*Pinus sylvestris*) and energy crops (*Miscanthus giganteus*).

After sewage sludge addition

CONCLUSIONS

- increased attention to climate change and mitigation of greenhouse gas emissions and thus recognized additional benefits of biodegradable waste applications to soils;
- there will be increased treatment of biodegradable waste with energy recovery through anaerobic digestion, incineration or other thermal treatment, with recycling of the ash and recovery of phosphate;
- there may be increased production and utilization of biogas from sewage sludge, as well as some production of alcohols and other fuels directly from biodegradable waste using pyrolysis and gasification;
- increased application of biodegradable waste to fuel crops such as *Miscanthus*, willows, hybrid poplars and other non-food energy crops;
- Biodegradable waste is being turned into a carbon neutral construction material that could replace traditional clay and concrete bricks;