

National Technical University of Athens School of Chemical Engineering

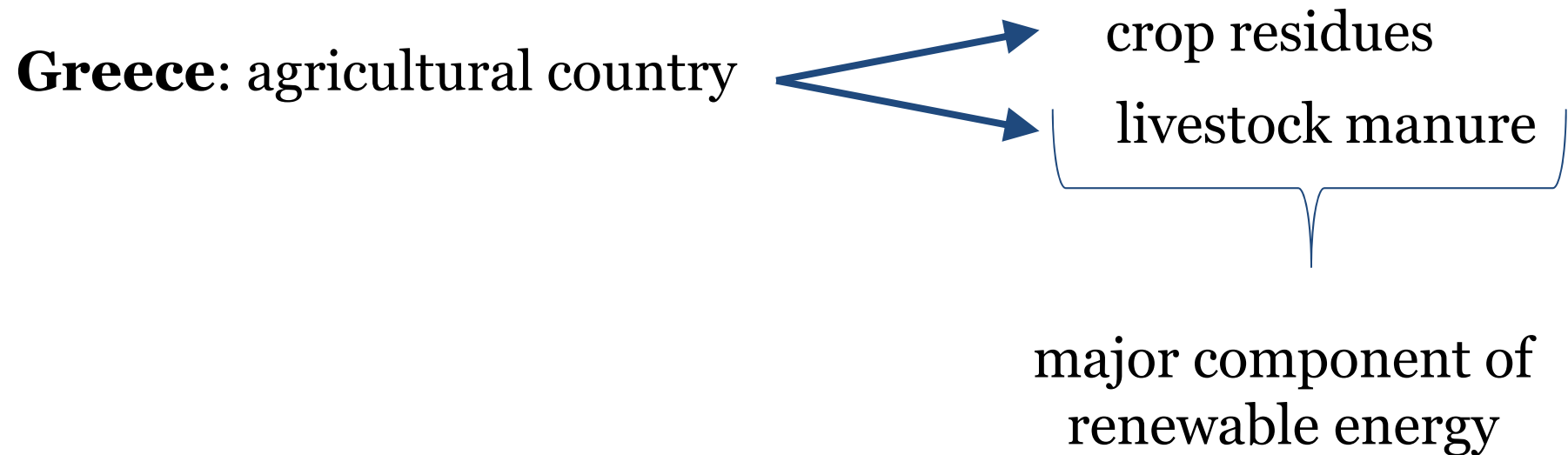
Challenges and opportunities of anaerobic digestion of agricultural residues and livestock manure in the regional unit of Florina, Greece

A. Lais¹, E.M. Barampouti², S. Mai^{2,*}

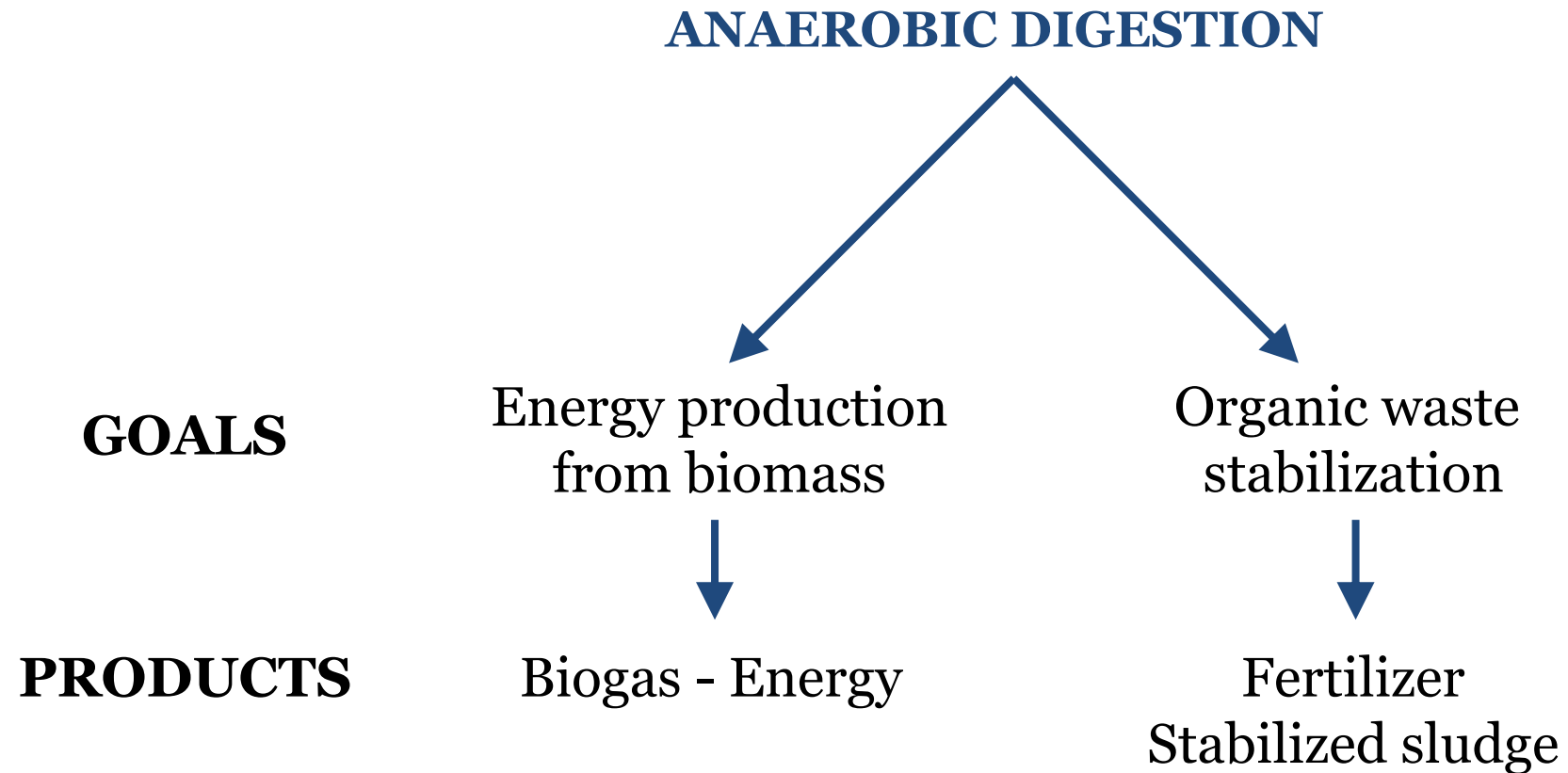
¹School of Science and Technology, HOU, 26222, Patras, Greece

²School of Chemical Engineering, NTUA, 15780, Zografou, Greece

Agro-industrial residues



Anaerobic digestion



Florina, Greece



→ West Macedonia

→ Florina regional unit



1. Florina

2. Amyntaio

3. Prespes

Population: 51.414 people

Cultivation species: wheat, beans, fruit trees (apple, pear, peach, almond, cherry trees)

Stock-breeding : goats, sheep and cattle

Aim

Assessment of the potential of biogas production based on the utilization of manure and crop residues in Florina.

Methodology - Results



Theoretical potential of annual crop residues

$$\text{THP_RAP} = \Sigma (\text{CA}_i * \text{AP}_i * \text{RtP}_i * \text{Av}_i)$$

where:

THP_RAP= primary agricultural residues (e.g. straw, stalks), in tonnes

CA_i = cultivated area of i crop, in decares (da)

AP_i = agricultural production of i crop, in tonnes per decare (t/da)

RtR_i = residue to product ratio of i crop

Av_i = availability of residues for i crop according to current harvesting system

Basic agricultural wastes in Florina, Greece (2015)

Cultivation species (i)	Production (t/y)	CA _i Cultivated area (da*)	Index			Residues (t/y)
			AP _i Agricultural production (t/da)	RtP _i	Av _i	
Cereals						
Wheat	9.819	49.098	0,20	0,69-2,57	0,22-0,85	5.028
Durum wheat	5.457	28.274	0,19	0,69-2,57	0,22-0,85	2.794
Barley	17.963	44.908	0,40	0,6-2,5	0,22-0,85	8.550
Maize	53.889	44.908	1,20	0,55-4,33	0,22-0,85	34.678
Rye	18.277	65.275	0,28	0,7-3,10	0,22-0,85	12.501
Oat	373	1.869	0,20	0,68-2,13	0,22-0,85	203

*1 da=0,1 ha =1000m²

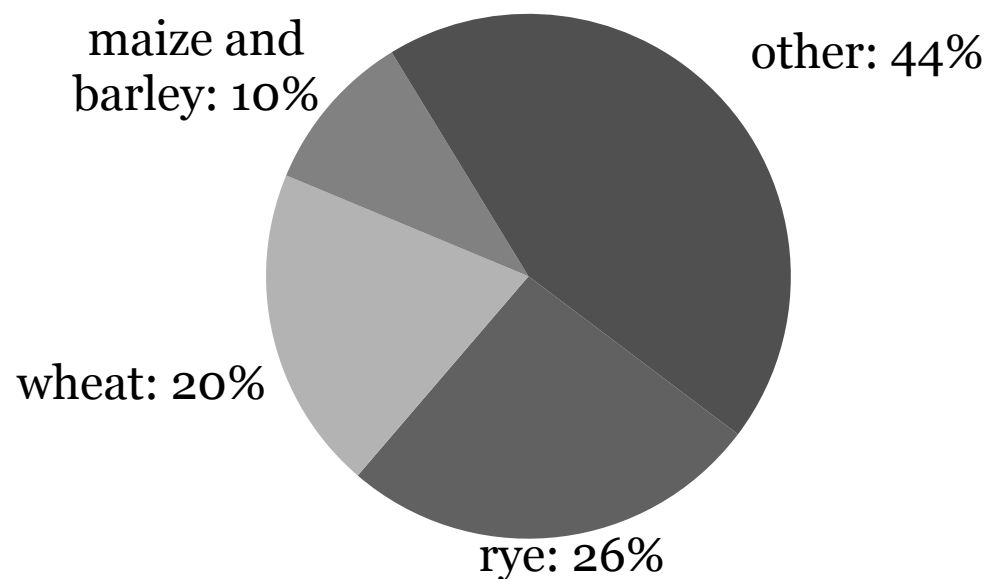
Basic agricultural wastes in Florina, Greece (2015)

Cultivation species (i)	Production (t/y)	CA _i Cultivated area (da*)	Index			Residues (t/y)
			AP _i Agricultural production (t/da)	RtP _i	Av _i	
Leguminous crops						
Lentils	48	407	0,12	0,8-2,10	0,22-0,85	29
Beans	2.980	9.934	0,30	0,8-2,10	0,22-0,85	1.693
Chickpeas	65	448	0,15	0,8-2,27	0,22-0,85	44
Industrial plants						
Tobacco	2	8	0,28	1,00-2,00	0,22-0,85	2
Sugarbeet	850	2.127	0,40	0,15-0,79	0,22-0,85	250
Potatoes	11.924	3.408	3,50	0,2-0,72	0,22-0,85	1.812
TOTAL						67.585

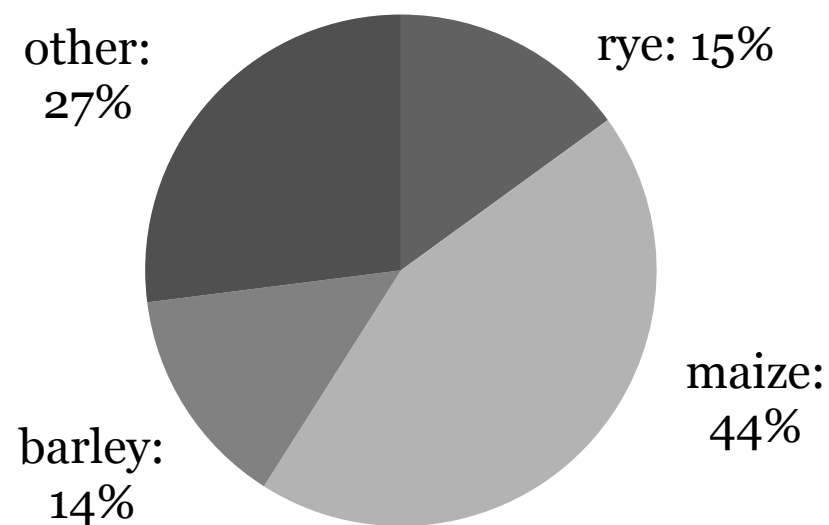
Basic agricultural wastes in Florina, Greece (2015)

The predominant species are in terms of:

Total cultivated area



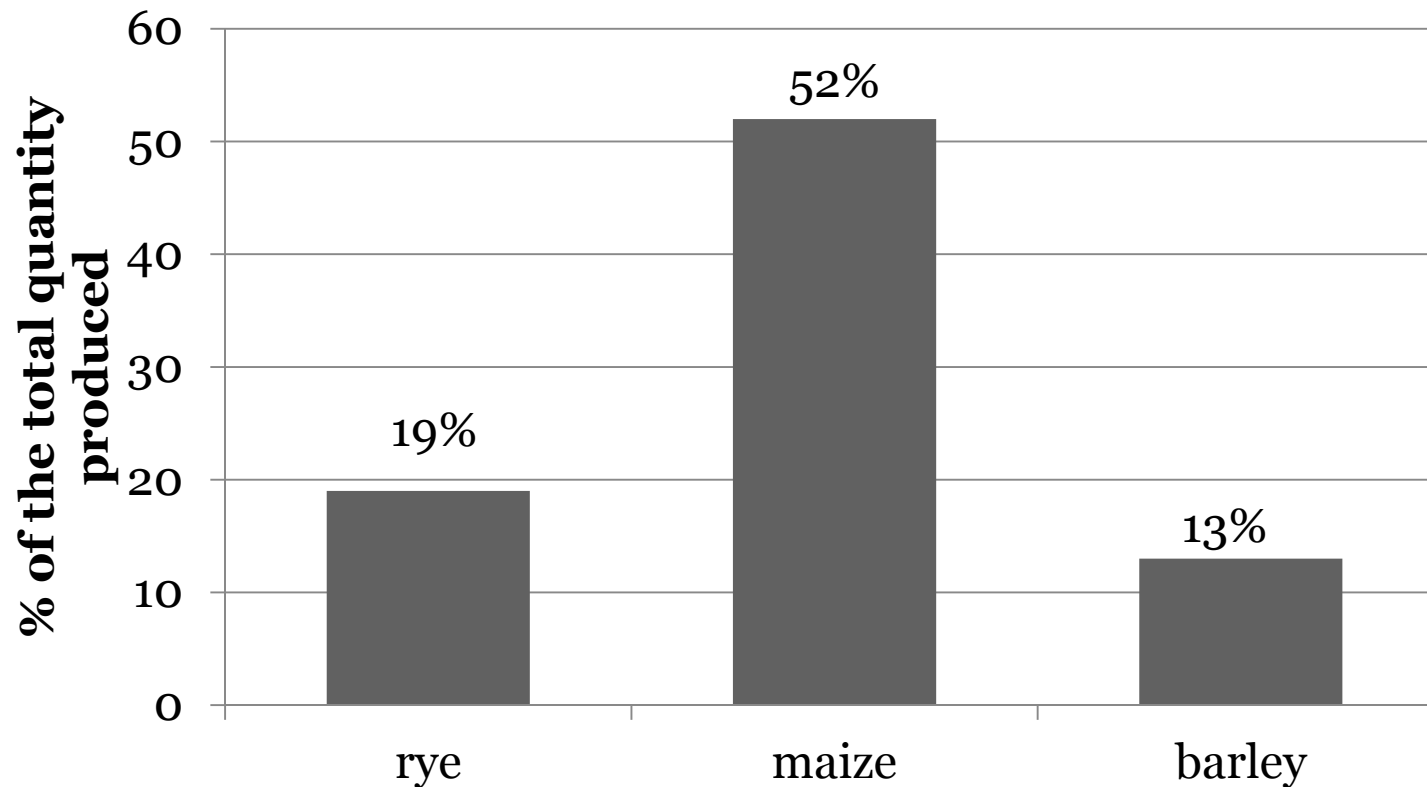
Produced product



Basic agricultural wastes in Florina, Greece (2015)

The predominant species are in terms of:

Residue production



Theoretical potential of fruit tree prunings

$$\text{THP_RAP}_{\text{pr}} = \Sigma [\text{Production}(\text{tn}) * \text{RtPr}_i * \text{Av}_i]$$

where:

$\text{THP_RAP}_{\text{pr}}$ = primary agricultural residues (prunings), in tonnes

RtPr_i = residue to product ratio of i crop

Av_i = availability of residues for i crop according to current harvesting system

Primary residues from cultivated trees in Florina, Greece (2015)

Cultivation species (i)	Total Area (da*)	Production (tn/y)	RtP _i	RtP _i	Av _i	Residues (tn/y)
Pears	507	300	0,54	0,38-0,79	0,80	130
Apples	3.568	10.200	0,53	0,32-0,83	0,80	4.325
Apricots	108	15	0,37	0,35-0,41	0,80	4
Peaches	9.405	23.903	0,35	0,3-0,4	0,80	6.693
Cherries	1.257	132	0,89	0,83-1,0	0,80	94
Almonds	1.185	93	2,74	1,9-3,57	0,80	203
Vines	9.375	7.351	0,65	0,5-0,83	0,80	3.822
TOTAL						15.271

The primary agricultural residues amount up to 82.813 tn/y

Theoretical manure potential

$$\text{THP_Manure} = \Sigma (\text{NHeads}_i * \text{MpH}_i)$$

where:

THP_Manure = theoretical potential of manure (tn/year)

NHeads_i = the number of heads for the i type of livestock

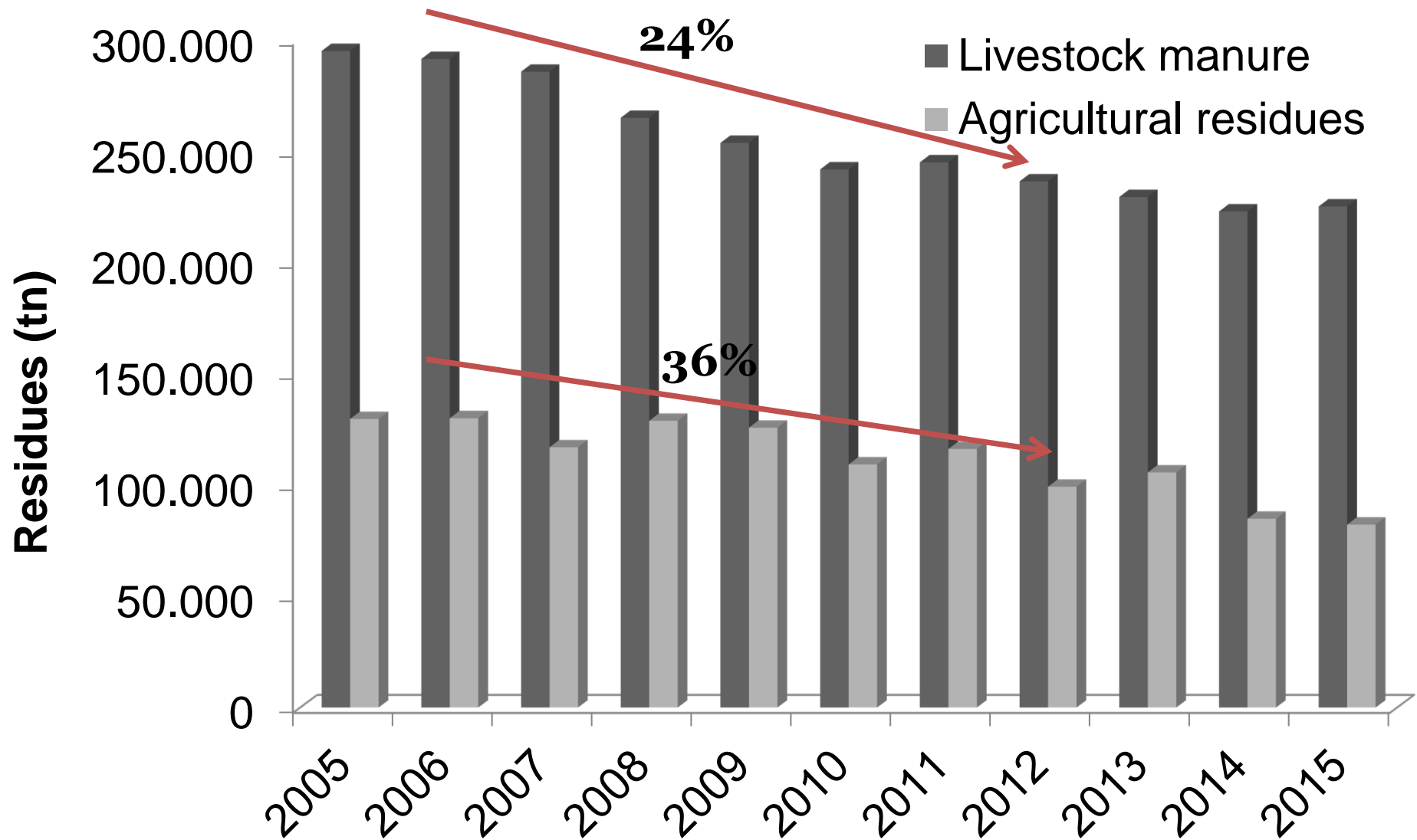
MpH_i = amount of manure for the i type of livestock, in tonnes per head = type of livestock, i.e. cattle, pig, poultry etc.

Number of animals and animal waste production in Florina, Greece (2015)

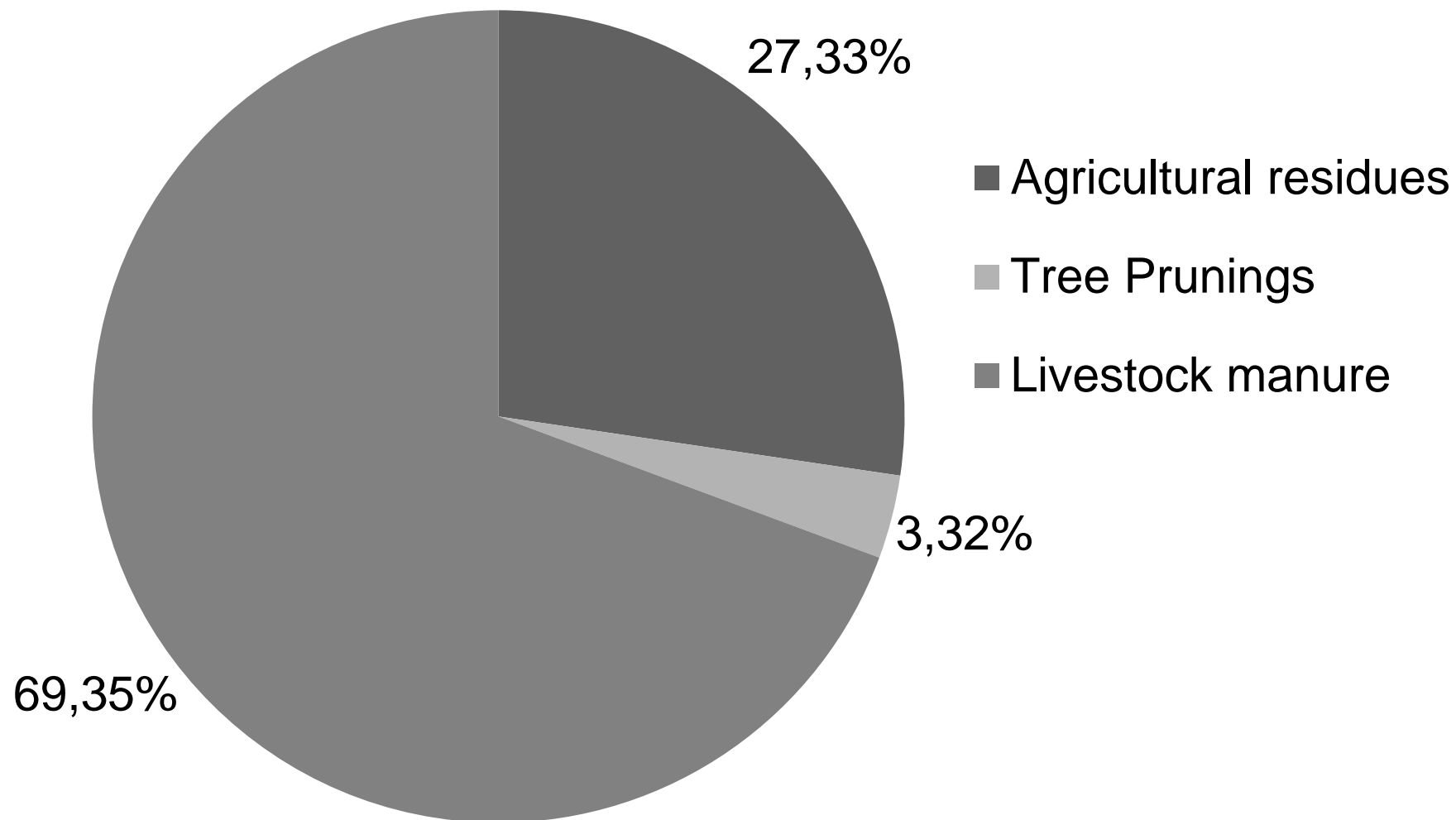
Animal species	NHeads; Number of animals	THP_Manure Theoretical potential of manure (tn/head)	THP_Manure (tn/head)	MpH_i Amount of manure (tn/y)
Cattle	13.834	8,81	4,50-12,78	121.878
Pigs	1.200	1,21	0,56-1,90	1.452
Goats and sheeps	143.831	0,71	0,17-1,20	102.120
TOTAL				225.663

The total agricultural residues amount up to 308.306 tn/y.

Agricultural residue and livestock manure production



Residues percentage per species

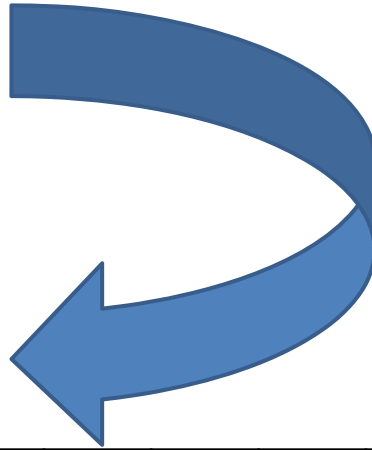


Monthly residue production throughout the year

	January	February	March	April	May	June	July	August	September	October	November	December
Wheat						█						
Barley						█						
Maize										█		
Rye						█						
Oat						█						
Lentils									█			
Beans									█			
Chickpeas									█			
Potatoes										█		
Tobacco						█						
Sugarbeet									█			
Tree prunings			█							█		
Animal waste	█											

Monthly residue production throughout the year

	January	February	March	April	May	June	July	August	September	October	November	December
Wheat												
Barley												
Maize												
Rye												
Oat												
Lentils												
Beans												
Chickpeas												
Potatoes												
Tobacco												
Sugarbeet												
Tree prunings												
Animal waste												



	January	February	March	April	May	June	July	August	September	October	November	December
Wheat						12,48	21,61	48,14				
Barley						42,27						
Maize										48,75	68,94	80,62
Rye						31,42	54,43					
Oat						0,39	0,67					
Lentils									0,35	0,06	0,08	
Beans									21,01	3,37	4,77	
Chickpeas												
Potatoes										5,92	8,37	
Tobacco									0,01			
Sugarbeet									5,61	0,90	1,27	
Tree prunings												
Animal	100,00	100,00	28,59	100,00	100,00	13,44	23,29	51,86	73,03	11,72	16,57	19,38

*Total energy potential through
anaerobic digestion*

Estimation of biogas and methane potential

	VS (%)	BMP* (m³/ kg VS)	CH₄ content (%)	CH₄ efficiency (m³/ kg residue)	CH₄ Potential (m³/y)	Biogas Potential (m³/y)
Cereals						
Wheat	76,10-85,37	0,15-0,45	51,50	0,24	1.206.625	2.342.961
Durum wheat	76,10-85,37	0,15-0,45	51,50	0,24	670.627	1.302.189
Barley	17,65-43,66	0,35-0,66	62,20	0,17	1.453.575	2.336.937
Maize	24,42-49,56	0,34-0,54	58,90	0,15	5.201.669	8.831.356
Rye	23,05-57,95	0,28-0,54	63,80	0,26	3.250.387	5.094.650
Oat	59,60-81-20	0,07-0,32	60,00	0,10	20.335	33.891

Estimation of biogas and methane potential

	VS (%)	BMP* (m³/ kg VS)	CH₄ content (%)	CH₄ efficiency (m³/ kg residue)	CH₄ Potential (m³/y)	Biogas Potential (m³/y)
Leguminous crops						
Lentils	13,00	0,29	60,00	0,04	1.164	1.941
Beans	13,31	0,24-0,35	60,00	0,04	67.711	112.852
Chickpeas	13,00	0,29	60,00	0,04	1.758	2.929
Potatoes	6,95-19,80	0,41-0,55	60,00	0,07	126.872	211.453
Industrial plants						
Sugarbeet	6,10-18,72	0,11-0,52	57,89	0,03	7.497	12.950

Estimation of biogas and methane potential

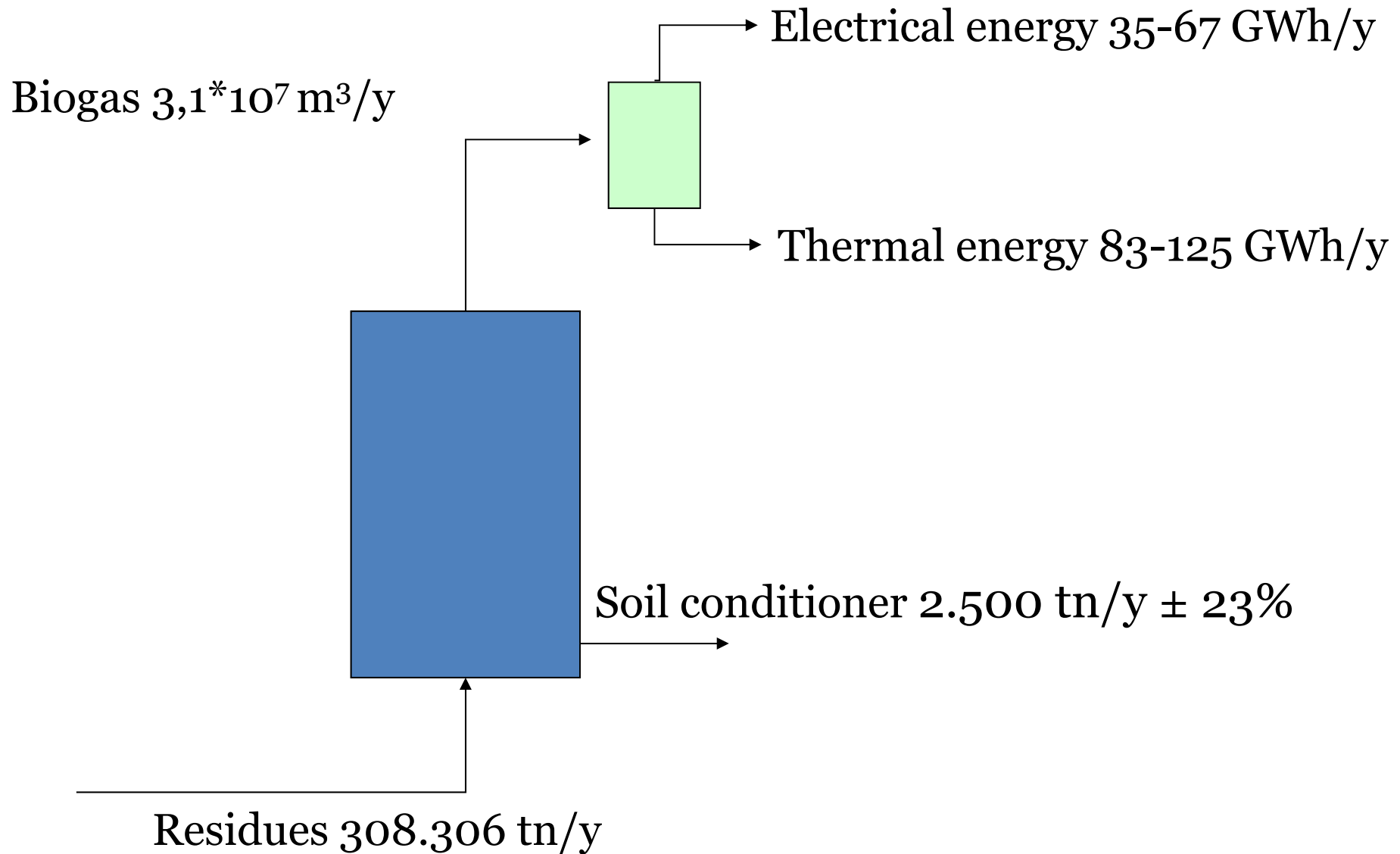
	VS (%)	BMP* (m³/ kg VS)	CH₄ content (%)	CH₄ efficiency (m³/ kg residue)	CH₄ Potential (m³/y)	Biogas Potential (m³/y)
Trees						
Pears	63,88-83,84	0,13	60,00	0,09	12.299	20.498
Apples	63,88-83,84	0,13	60,00	0,09	410.424	684.039
Apricots	63,88-83,84	0,13	60,00	0,10	421	702
Peaches	63,88-83,84	0,13	60,00	0,10	635.137	1.058.562
Cherries	63,88-84,20	0,13	60,00	0,10	8.919	14.865
Almonds	63,88-83,84	0,13	60,00	0,09	19.269	32.115
Vines	91,97	0,134	60,00	0,12	373.909	623.181
TOTAL					1.460.378	2.433.963

Estimation of biogas and methane potential

	TS (%)	VS (% TS)	BMP (m³/ kg VS)	CH₄ content (%)	CH₄ Potential (m³/y)	Biogas Potential (m³/y)
Cattle	10,40	8,17	0,12-0,46	58,79	1.696.616	2.885.891
Pigs	7,00	5,44	0,25-0,50	66,82	20.066	30.030
Goats and sheeps	33,65	27,66	0,197-0,201	59,40	3.356.116	5.650.027
TOTAL					5.072.798	8.565.948

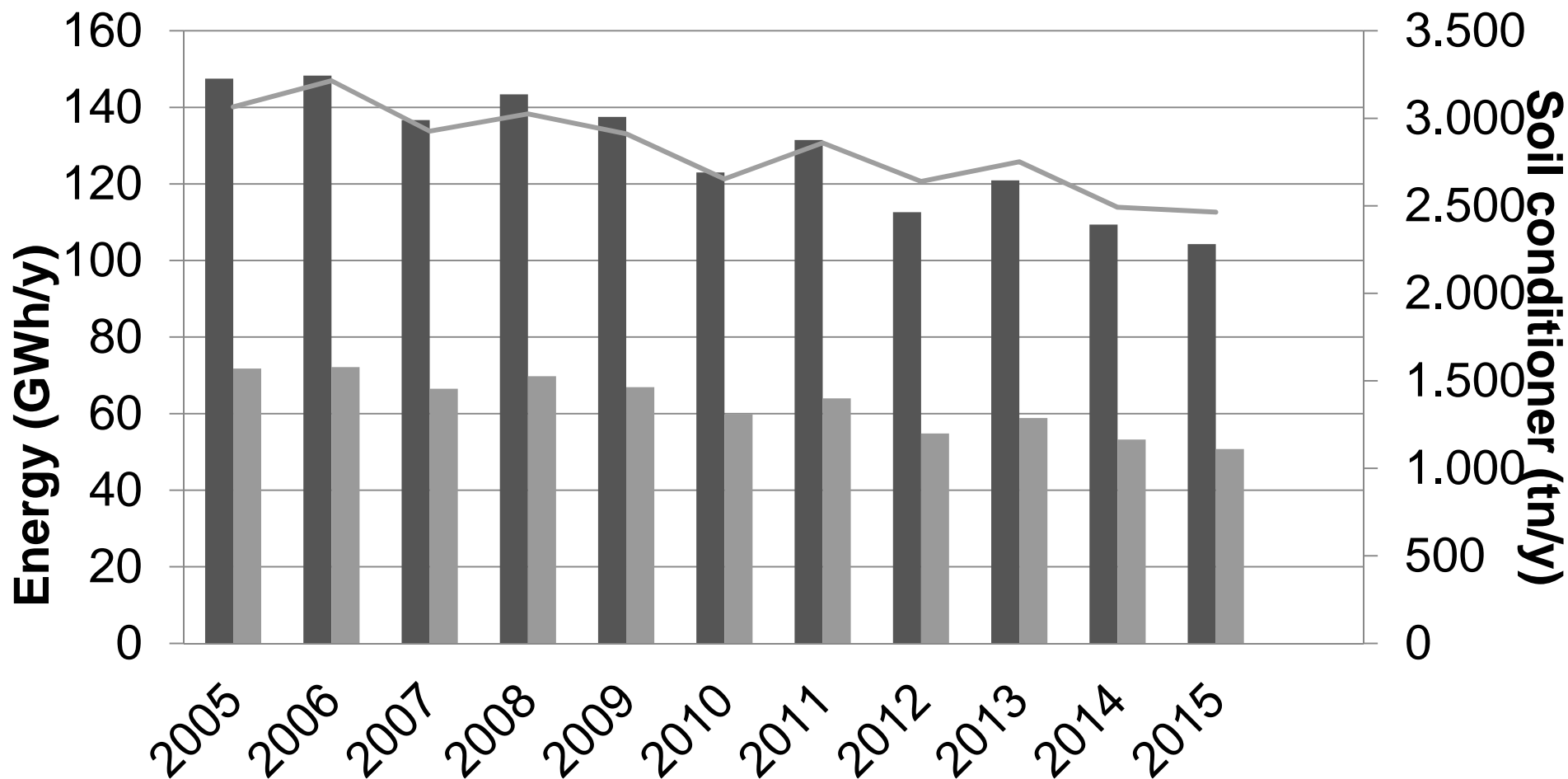
In the region of Florina the **total biogas potential** from agricultural residues amounts up to **31.284.022 m³/y**, with 73% coming from primary agricultural residues whereas the rest is due to livestock manure.

Utilization of residues by anaerobic digestion



Electricity, thermal energy and soil conditioner production

■ Thermal energy ■ Electrical energy — Soil conditioner



Electricity, thermal energy and soil conditioner production

- The potential of energy production has **declined** during the last decade as was the case for the residues production.
- In the regional unit of Florina, the **total electricity consumption** was 181 GWh and the respective consumption for agricultural use was equal to 37,5 GWh.
- Electricity produced from agricultural and manure residue could contribute by **20-36%** to the total energy needs and turn agricultural activities totally energy independent.

Conclusions



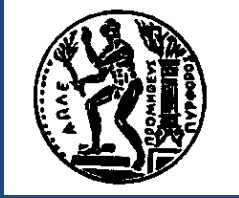
Florina: the most dedicated region in agro-industrial activities in West Macedonia

Total annual residues production: 308.306 tn/y

- agricultural residues (27%)
- livestock manure (73%)

Anaerobic digestion → 35-67 GWh/y electricity

Florina could exploit its renewable energy sources, under an environmental friendly way.



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