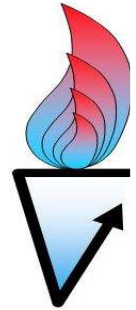




Anaerobic digestion of livestock effluents and energy crops in Italy

David Bolzonella



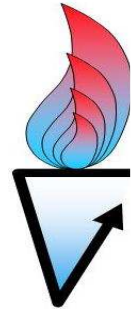


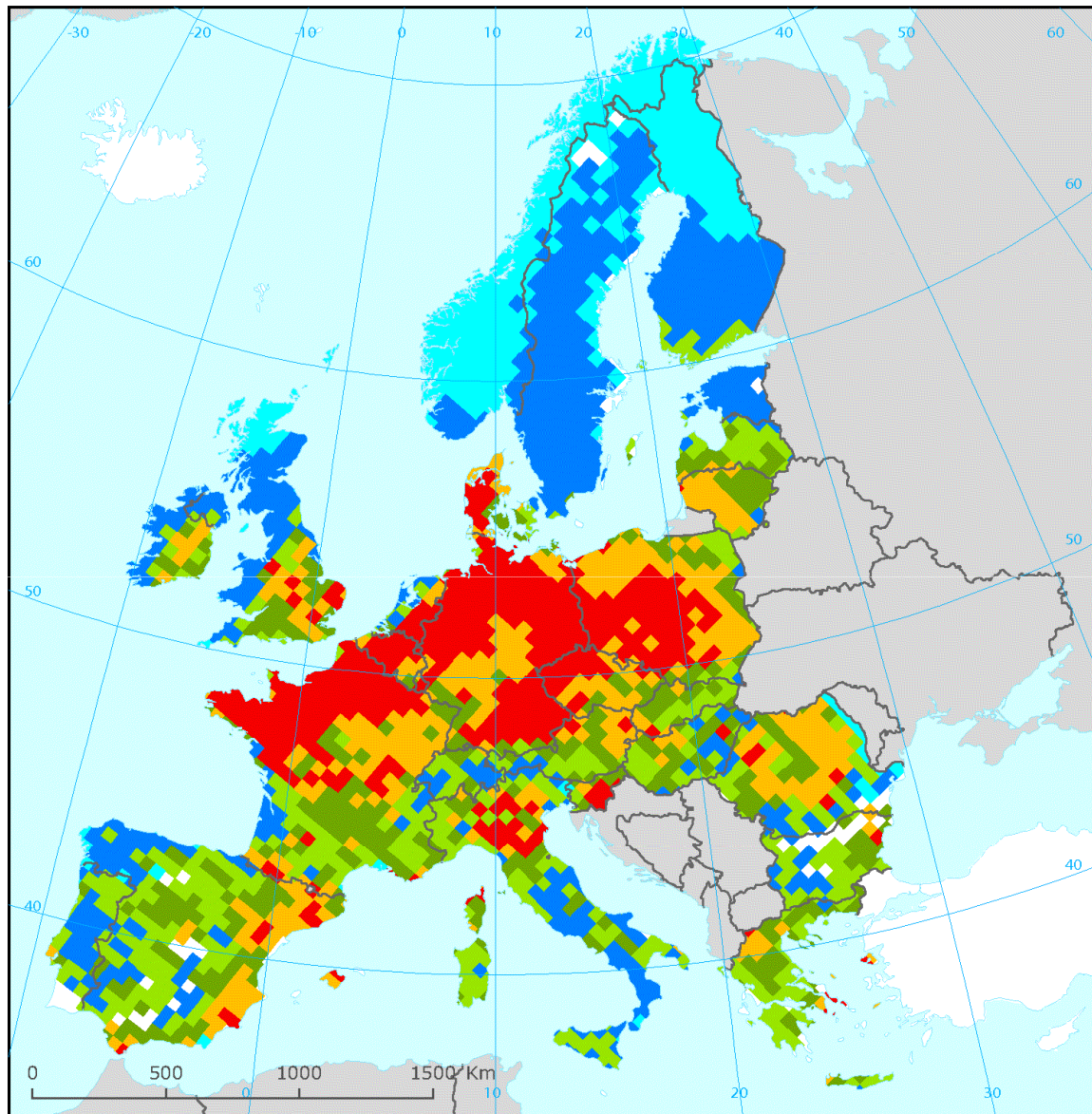
Background

Historically, livestock effluents are applied on agricultural soils. But the same soils also receive mineral fertilizers (like urea or ammonia salts).

Unfortunately, these fields are generally over loaded in terms of nitrogen and high concentrations of nitrates are therefore found in rivers, lakes and groundwater.

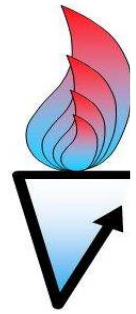
That's why in 1991 the EC introduced the Directive 91/676/CEE or "Nitrate Directive"
(please note the same year the 91/271/CEE focused on wastewater treatment, to prevent water bodies from both diffuse and point source pollution)





Exceedance of critical loads of nutrient nitrogen, 2004

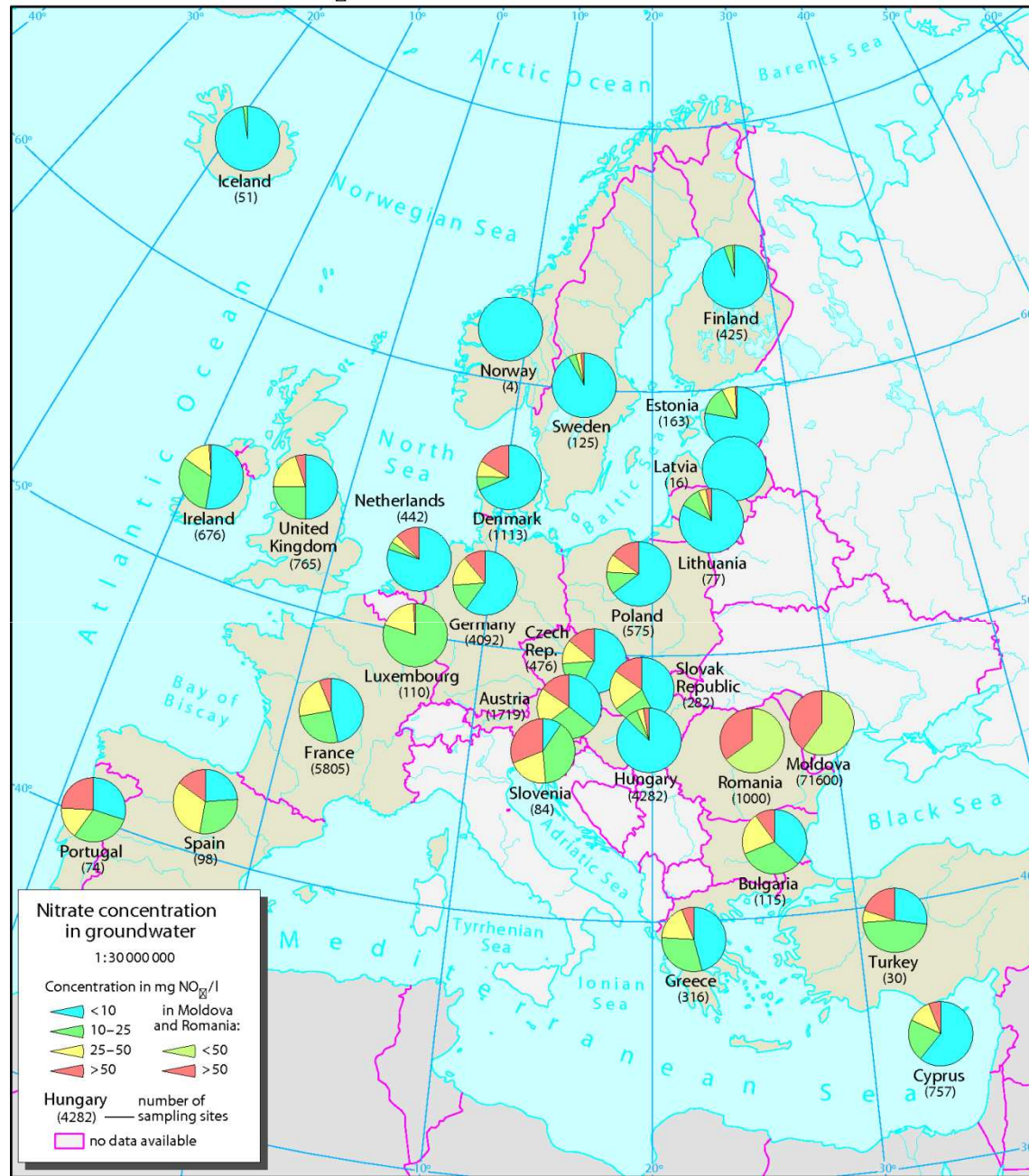
- eq ha⁻¹ a⁻¹
- No exceedance
 - < 200
 - 200–400
 - 400–600
 - 600–800
 - > 800
 - No data
 - Outside study area



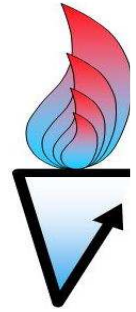
Source www.eea.europa.eu



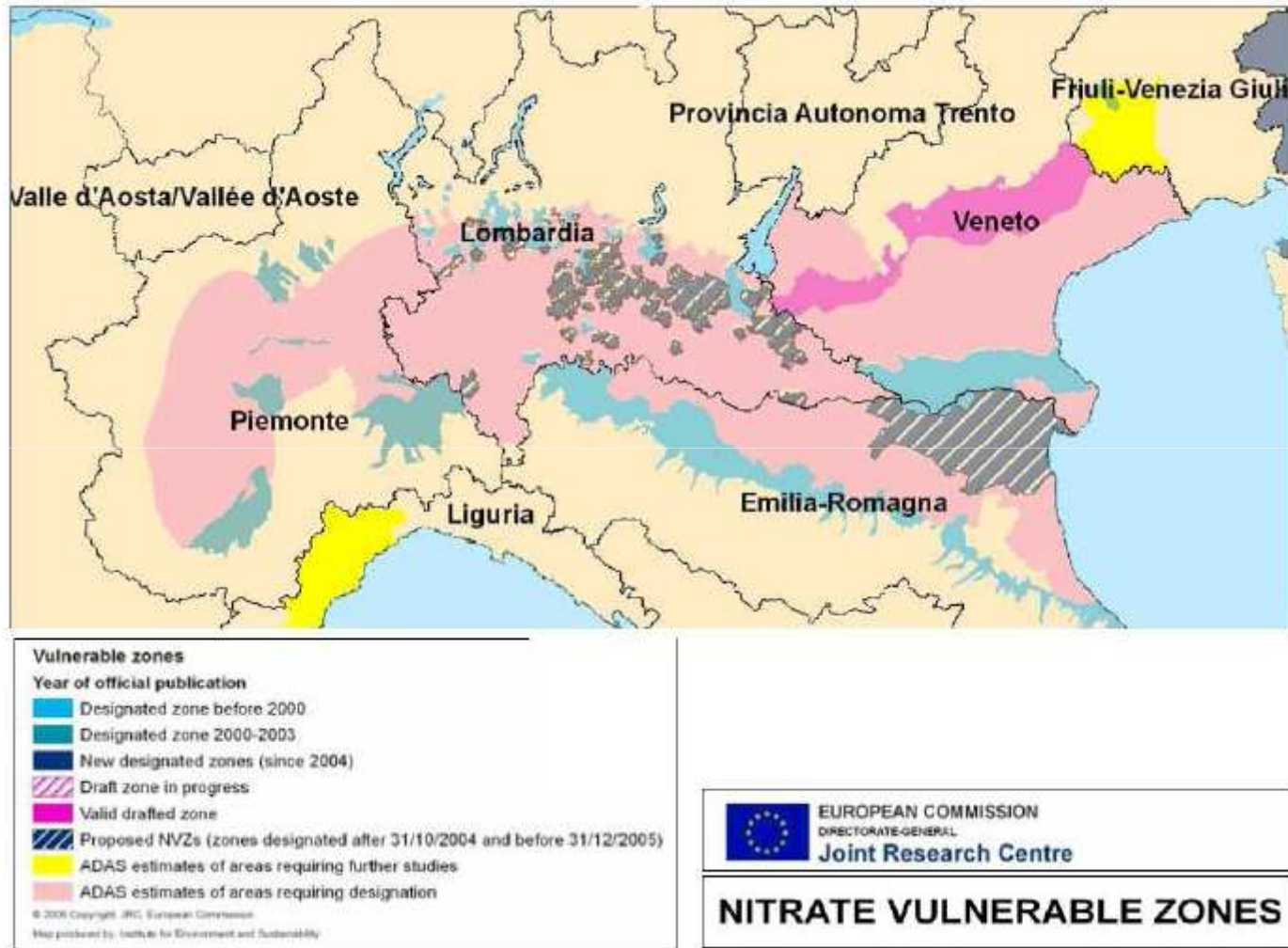
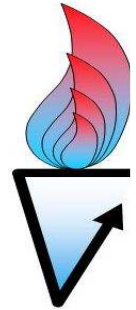
Map 9.4 Nitrate concentration (mg NO₃/l) in groundwater – frequency distribution at a country level.



Source
http://ec.europa.eu/environment/water/water-nitrates/index_en.html



This is a problem of major concern in north-Italy (Po valley) and in the Veneto Region in particular

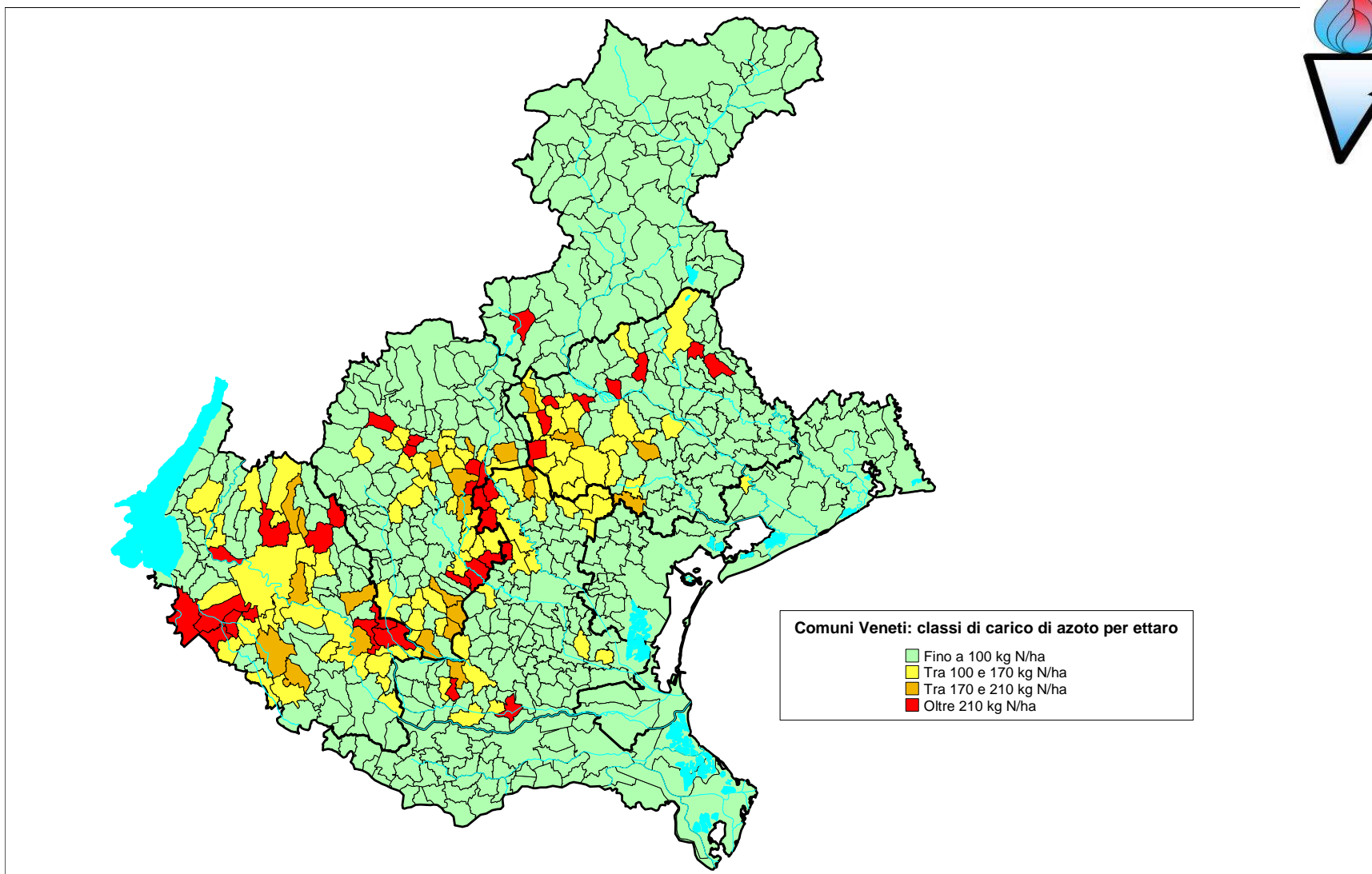
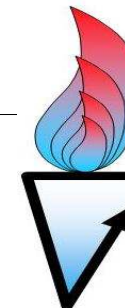


This is a problem of major concern in north-Italy (Po valley) and in the Veneto Region in particular





Nitrogen loading in the Veneto Region (kgN/ha year)





Livestock units in the Veneto Region (2007)



950,000 units



800,000 units



< 30,000 units

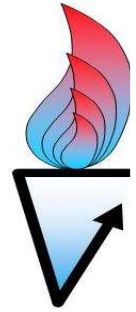


53 million units

(and 5 million people !)

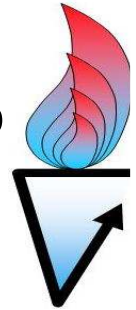


< 30,000 units





Because of this situation the Italian Government decided to support the production of biogas in farm plants with an installed power up to 1 MW and feeding material coming from a distance lower than 30 km with a subsidy of



0.28 € per kWh for 15 years

(that is up to 6,200 € per day for a 1MW unit working 22 hrs/day

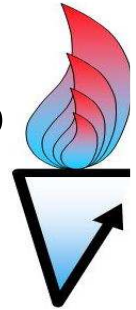
And what about heat ?!?!)

The basic idea for this was to use the revenues for nitrogen management (removal and/or recovery)





Because of this situation the Italian Government decided to support the production of biogas in farm plants with an installed power < 1 MW feeding material coming from an area less than 30 km with a subside of



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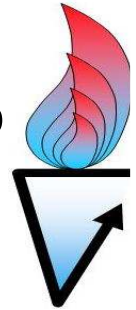
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kWh



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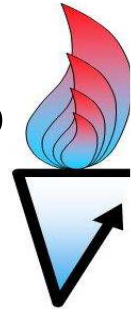
kWh



€



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And what about heat ?!?!)

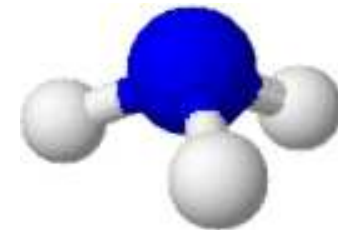
The basic idea for this was to use the revenues for nitrogen management (removal and/or recovery)



kWh



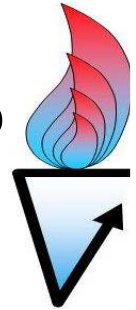
€



NH₃



Because of this situation the Italian Government decided to support the production of biogas in farm plants with an installed power < 1 MW feeding material coming from an area less than 30 km with a subside of



0.28 € per kWh for 15 years

(that is up to 6,200 € per day for a 1MW unit working 22 hrs/day
And what about heat ?!?!)

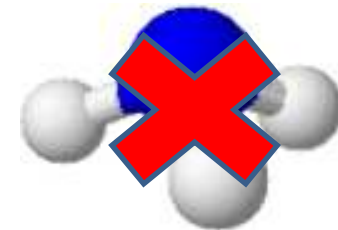
The basic idea for this was to use the revenues for nitrogen management (removal and/or recovery)



kWh



€



NH₃



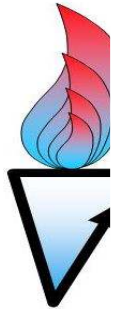
The second driver is clearly the necessity for renewable energy

Wholesale prize (as function of the energy mix)

2003

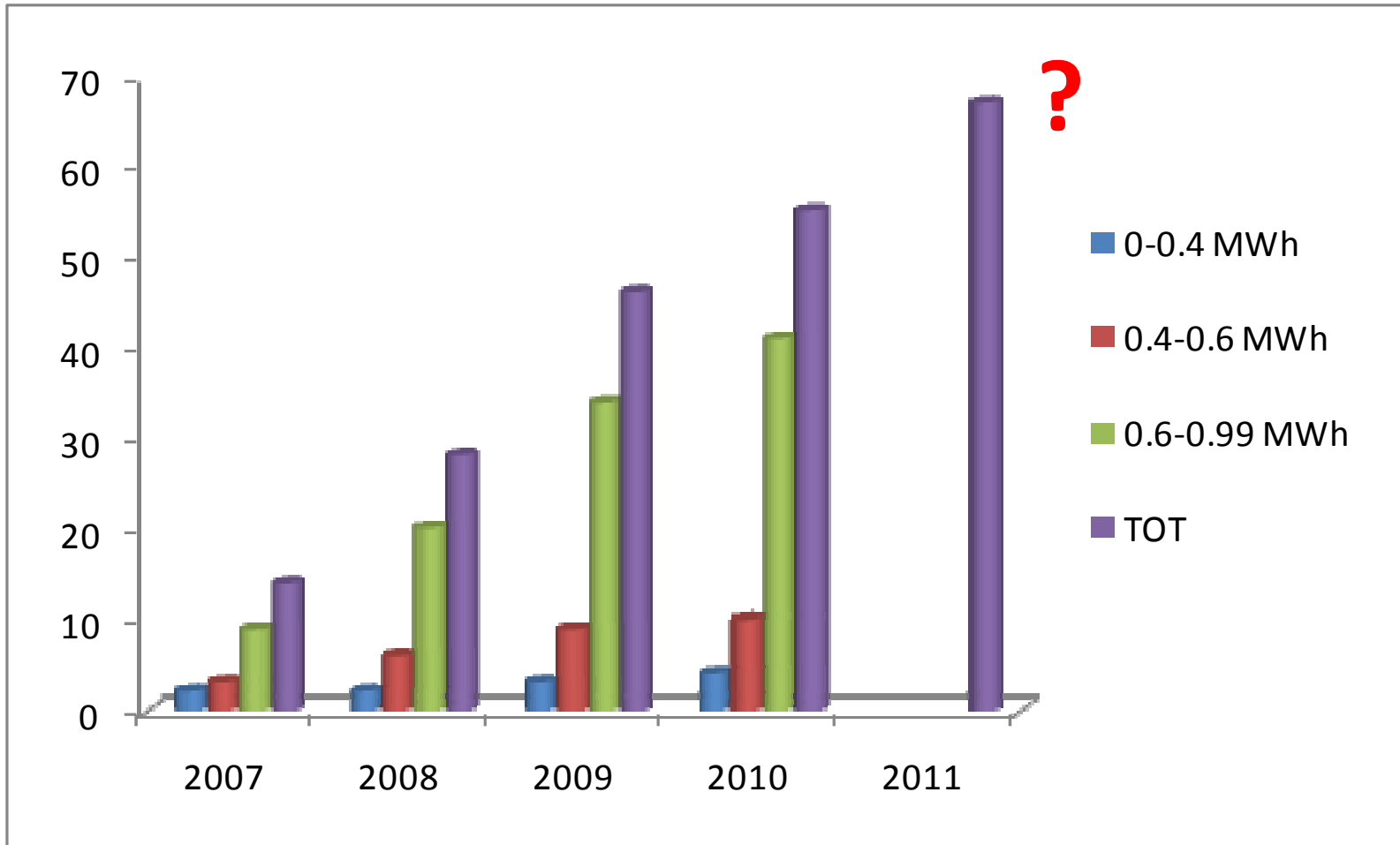
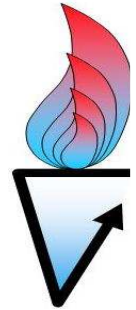


Fonte: Enerdata database (Gennaio 2004)



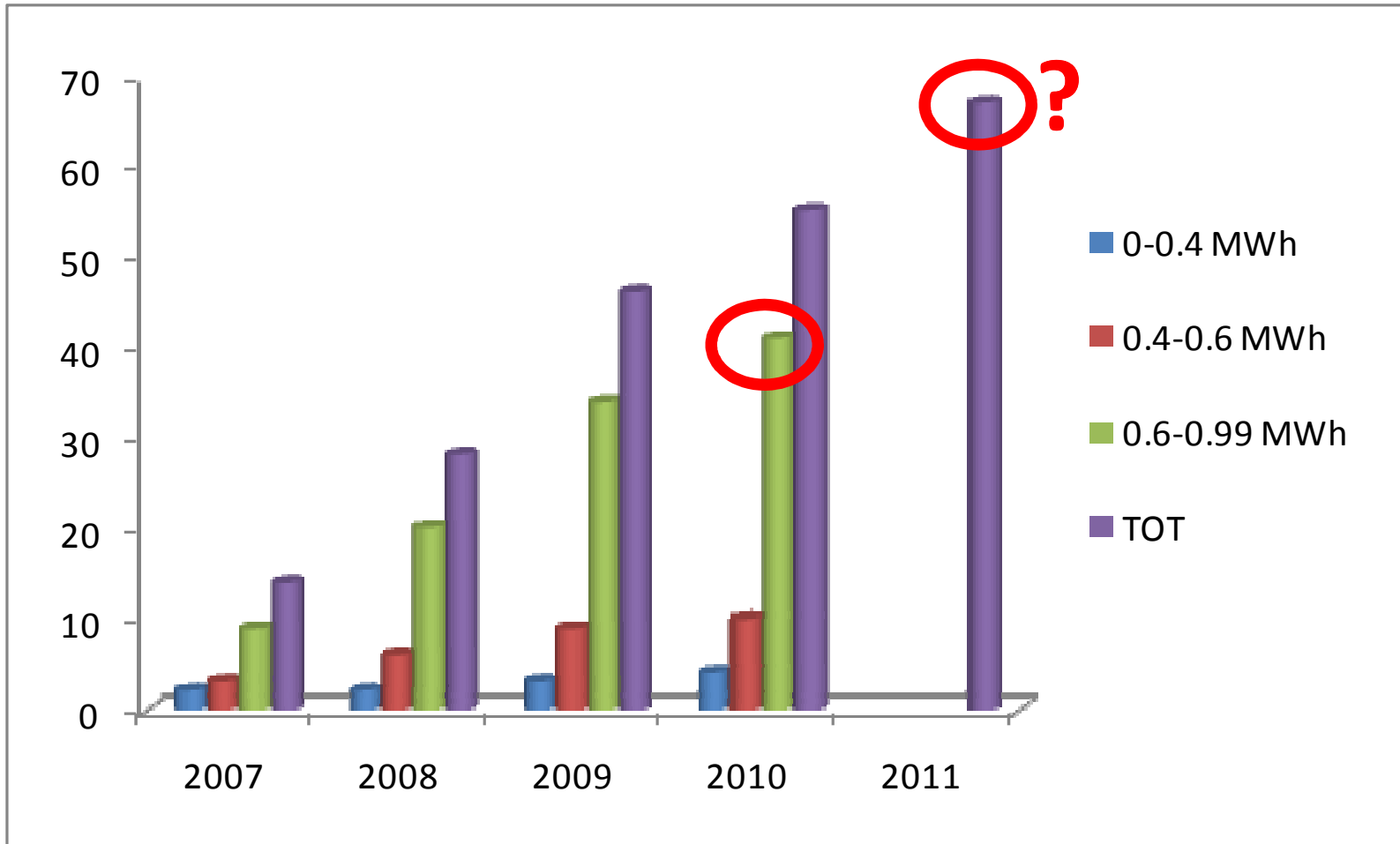
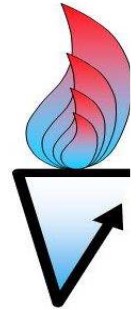


Because of the large subsidies the number of AD plants in farms of the Veneto Region is sky-rocketing





Because of the large subsidies the number of AD plants in farms of the Veneto Region is sky-rocketing

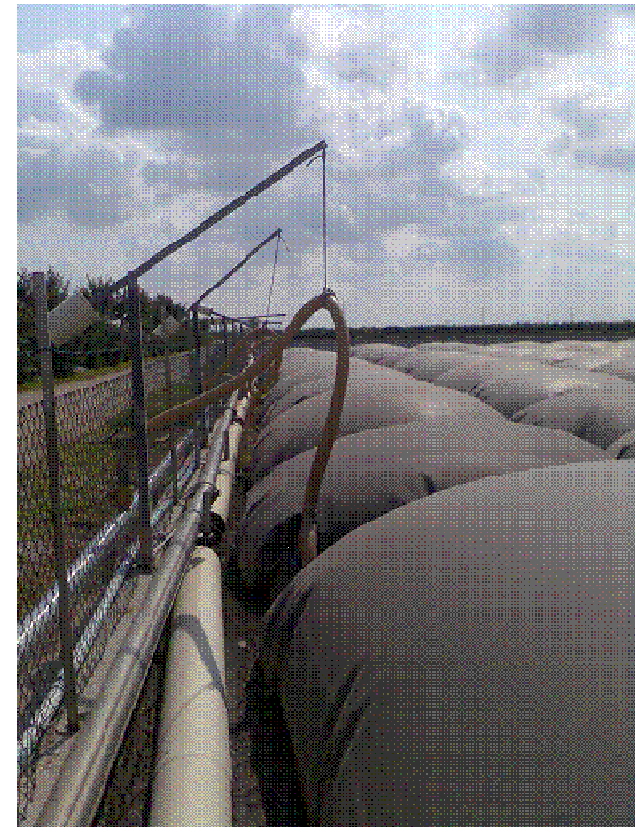




We carried out a survey on farm plants in the framework of the Riducareflui project coordinated by Veneto Agricoltura (Veneto Region owned)

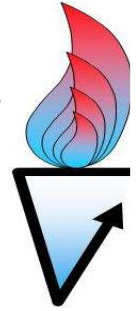


We considered “old” plants



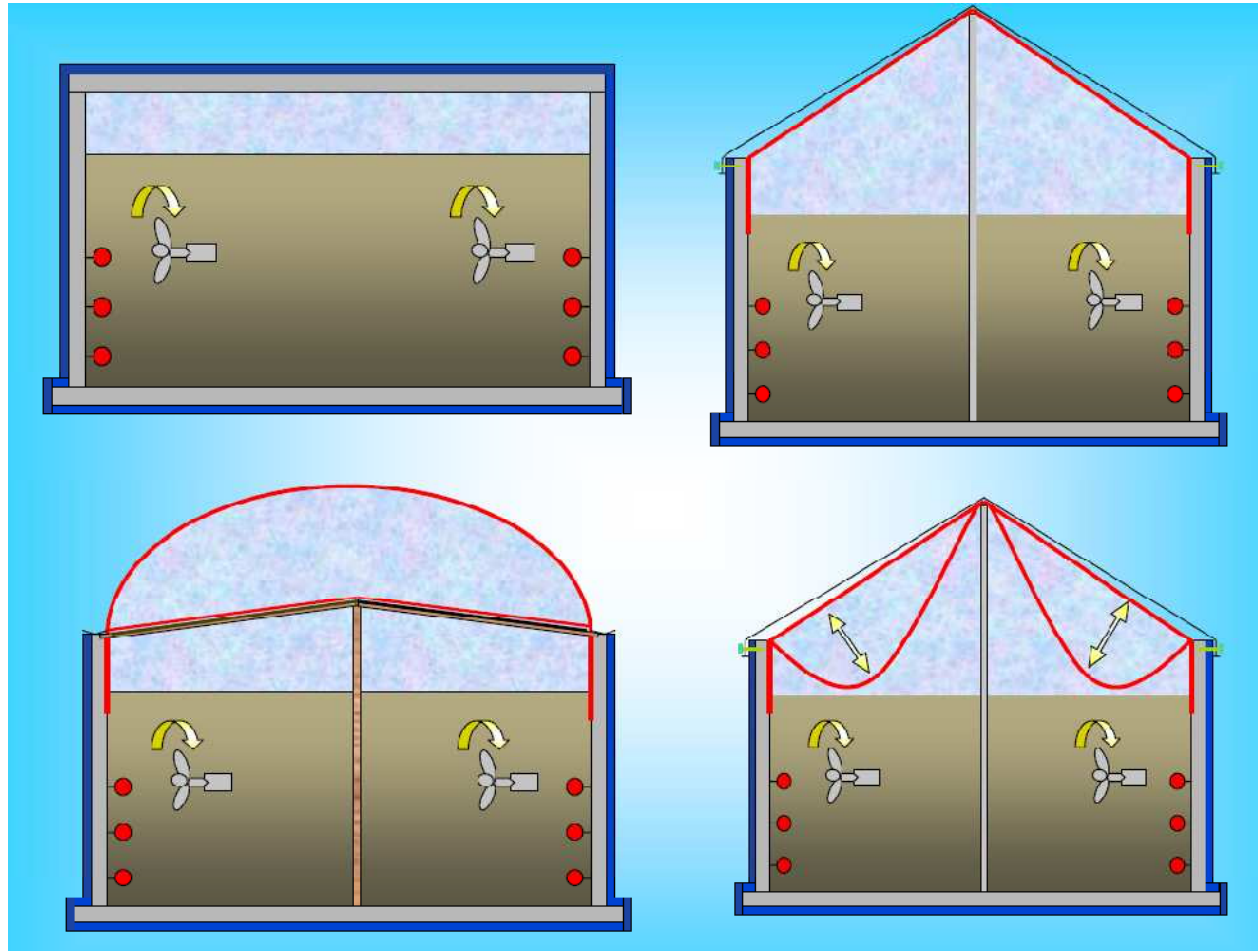
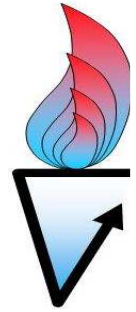


... with small CHP units ... (treating livestock effluents only) ...

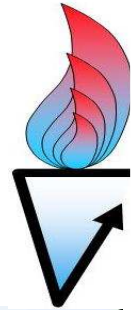




These are basically derived from old storage tanks

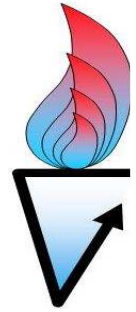


... and “brand new” plants (treating energy crops mainly)



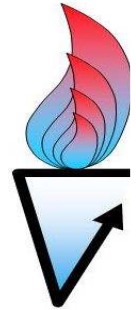


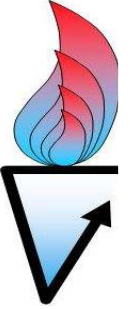
... with huge reaction volumes and CHP units





These all are plants using German/Austrian technologies



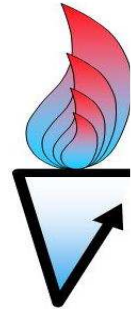


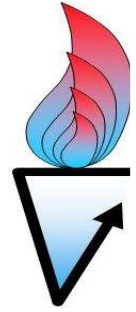
Primary and secondary digesters by BTS





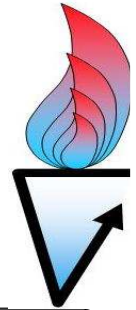
Coccus[®] digester by Schmack







Looking at feeding composition, operational conditions and yields of digesters we see that

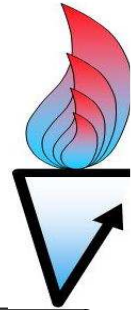


Plant	Substrate			
	1	2 ^a	3	4
I	Piggery effluent	---	Milk serum	---
II	Piggery effluent	Energy crops	Glycerol	Agro-waste
III	Cow effluent	Energy crops		Agro-waste
IV	Poultry effluent	Energy crops		Agro-waste
V	Cow effluent	Energy crops	Glycerol	Agro-waste
VI	Cow and poultry effluent	Energy crops		Agro-waste
VII	Cow effluent	Energy crops	Glycerol	Agro-waste

Plant	OLR	HRT	T	Yields, SGP	Yields, GPR	CH ₄	CHP
	kgVS/m ³ day	days	°C	m ³ /kgVS fed	m ³ /m ³ day	%	kW _{ee}
I	0.5	175	32 - 33	0.28	0.5	50 - 60	80
II	3.0	45	38 - 40	0.44	1.33	59 - 61	1042
III	2.1	42	N@	0.57	2.7	N@	845
IV	1.1	140	38 - 40	0.55	1.0	50	1042
V	3.0	77	39 - 41	0.60	1.76	49 - 51	1064
VI	3.5	67	38 - 40	0.52	1.88	49 - 51	845
VII	1.7	77	40 - 42	0.49	1.20	50 - 51	1035



Looking at feeding composition, operational conditions and yields of digesters we see that



Plant	Substrate			
	1	2 ^a	3	4
I	Piggery effluent	---	Milk serum	---
II	Piggery effluent	Energy crops	Glycerol	Agro-waste
III	Cow effluent	Energy crops		Agro-waste
IV	Poultry effluent	Energy crops		Agro-waste
V	Cow effluent	Energy crops	Glycerol	Agro-waste
VI	Cow and poultry effluent	Energy crops		Agro-waste
VII	Cow effluent	Energy crops	Glycerol	Agro-waste

Plant	OLR kgVS/m ³ day	HRT days	T °C	Yields, SGP m ³ /kgVS fed	Yields, GPR m ³ /m ³ day	CH ₄ %	CHP kW _{ee}
I	0.5	175	32 - 33	0.28	0.5	50 - 60	80
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III	2.1	42	N@	0.57	2.7	N@	845
IV	1.1	140	38 - 40	0.55	1.0	50	1042
V	3.0	77	39 - 41	0.60	1.76	49 - 51	1064
VI	3.5	67	38 - 40	0.52	1.88	49 - 51	845
VII	1.7	77	40 - 42	0.49	1.20	50 - 51	1035



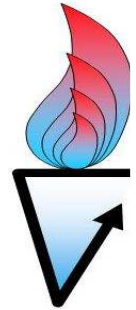
Maize

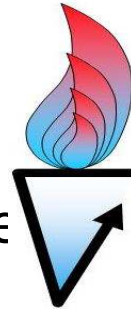


Typical energy crops (EC)
grown in the Po valley

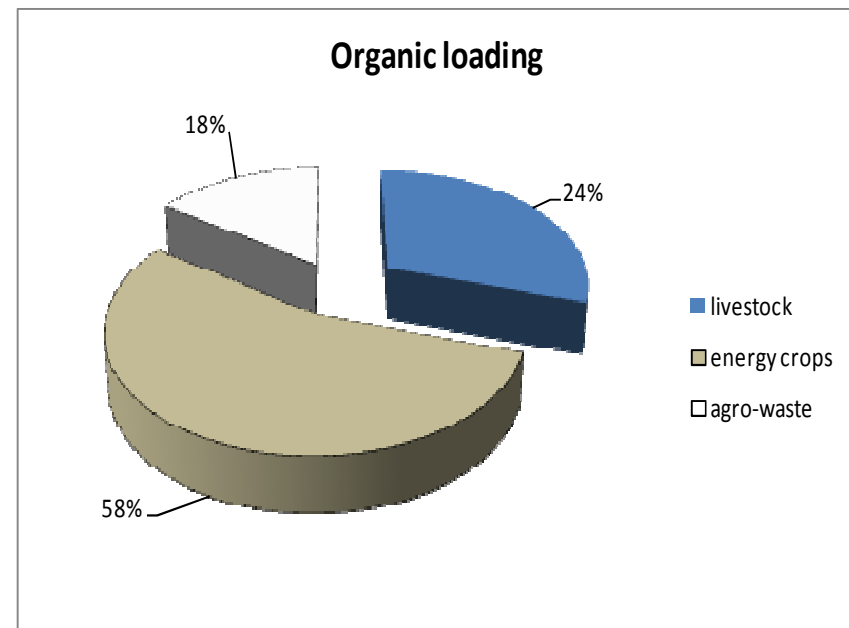
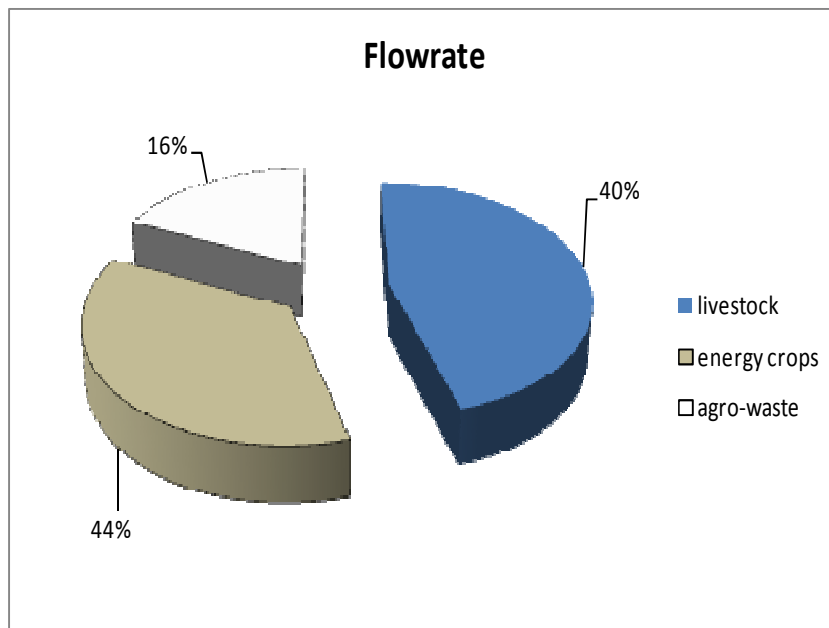


Triticale





These AD plants born to and are supposed to treat livestock effluents but They basically treat energy crops, maize-silage and triticale being by far the most abundant feed material !

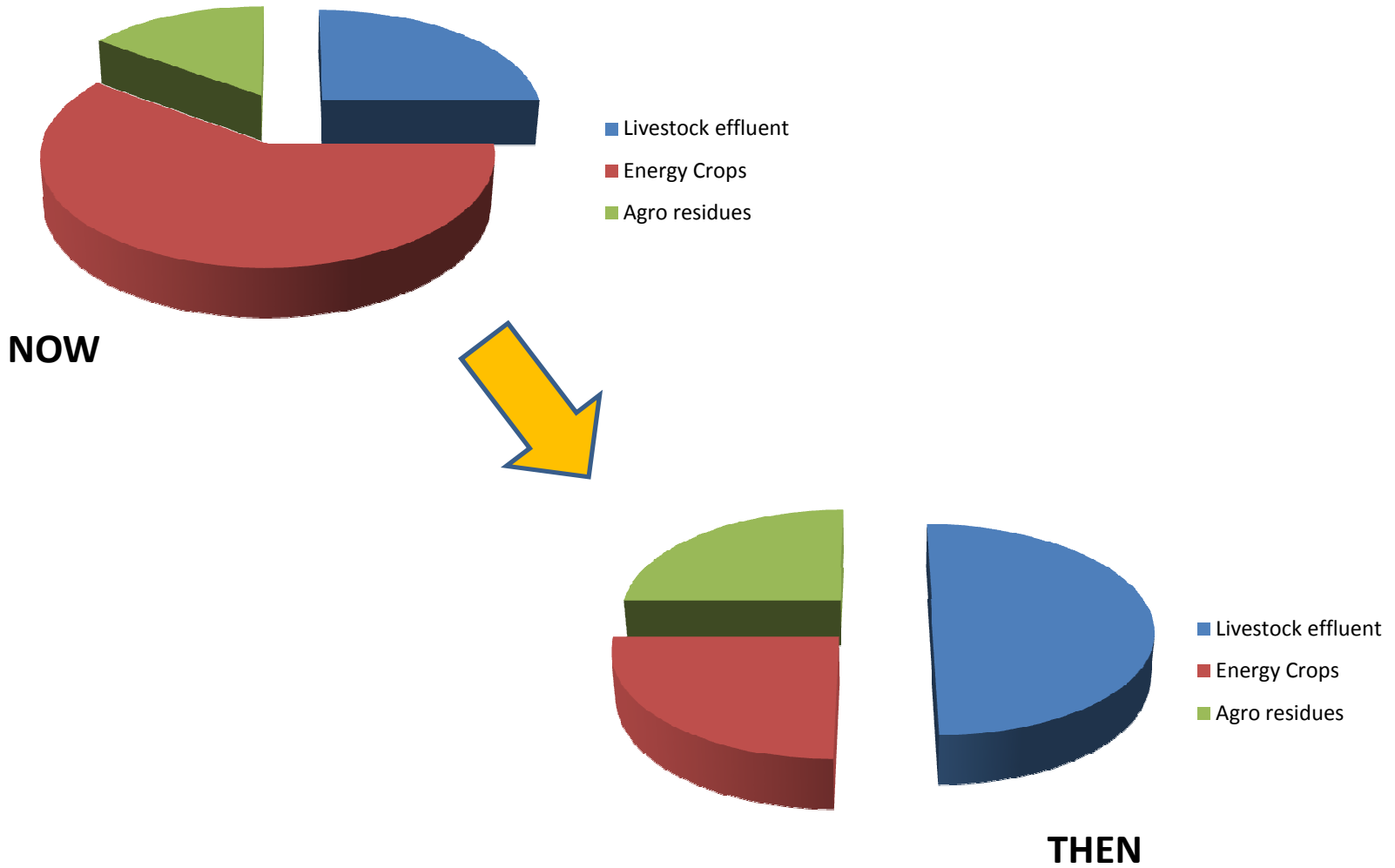


Energy crops use land, fertilizers, oil, manpower, water and cost some 30-40 € per tonne (but very site-specific because of yield: 40-45 tonnes/ha per year in North Italy)

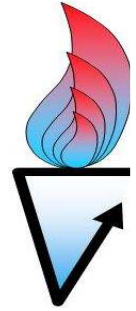




Changing the paradigm



So several other substrates (agro-waste from food crops processing) can be used for the purpose of renewable energy



Sweet corn



Beans

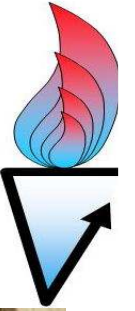


Tomato peel

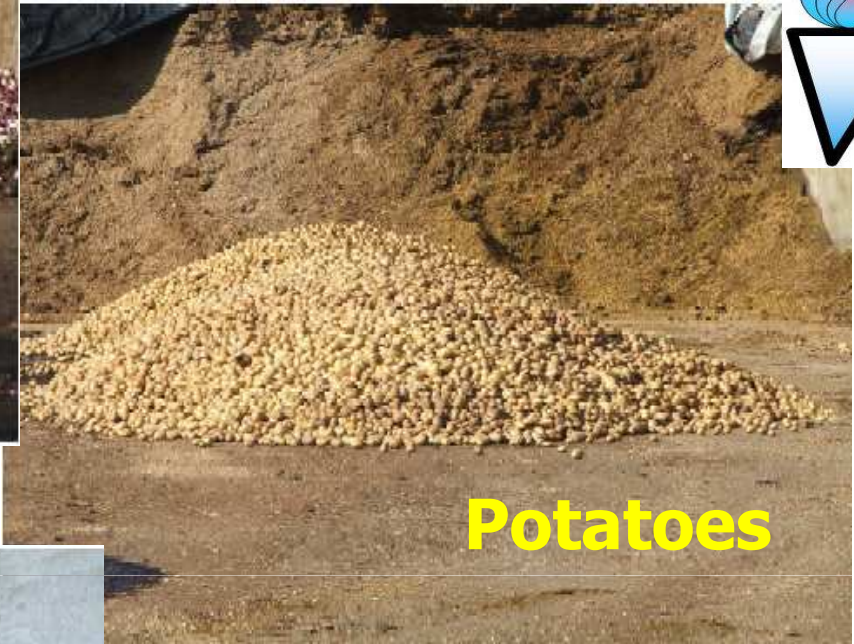


Peas





Salad



Potatoes

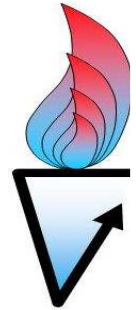


Onions



Fruit marc





Seasonal, but covering the whole year
(in the Mediterranean Region)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tomatoes								■	■	■		
Peas, beans, maize					■	■	■	■	■			
Apples, pears	■	■								■	■	■
Apricots, peaches						■	■	■				
Fruit marc	■	■	■	■							■	■
Vinasses			■	■						■	■	■
Livestock effluents	■	■	■	■	■	■	■	■	■	■	■	■





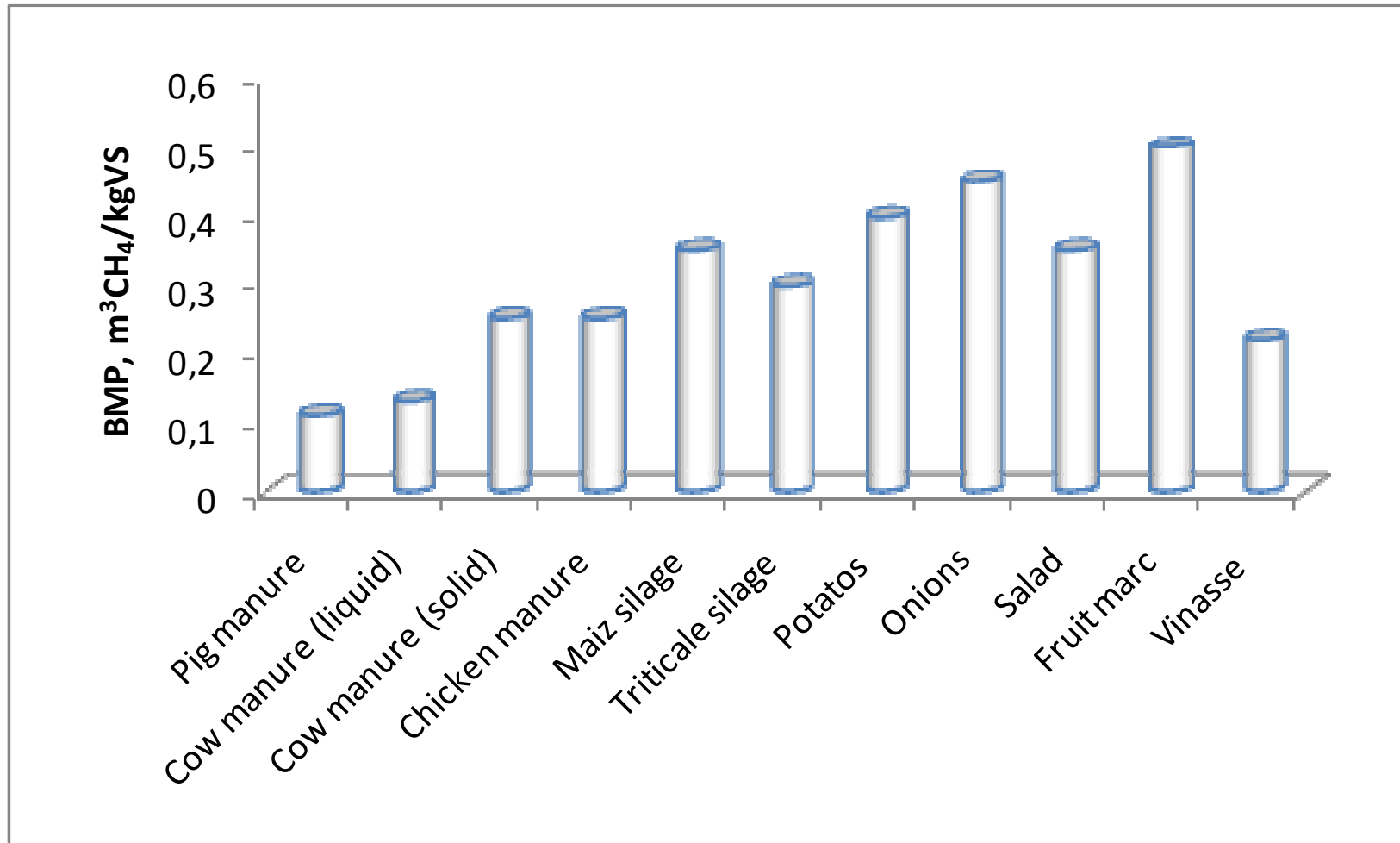
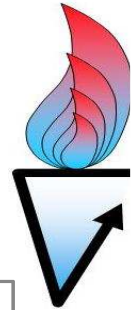
With similar characteristics and biogas potential of Energy Crops (EC)

Parameters	Total solids (TS)	Total volatile solids (TVS)	TVS/TS	COD	N	P
Substrates	g/kg	g/kg	%	g/kg dm	mg/kg dm	mg/kg dm
Dairy manure (solid)	260-350	250-315	78-84	880-930	34-49	6.0-7.8
Dairy manure (liquid)	89-97	69-76	76-89	910-1020	31-41	7.6-8.1
Piggery	60-90	47-76	66-83	860-965	18-42	4.2-8.5
Poultry (litter)	467-688	397-530	72-87	751-1000	27-47	11.8-20.1
Duck (liquid)	124-190	105-155	81-88	802-871	27-39	10.7-11.6
Rabbit manure	192-255	154-213	80-84	803-970	19-21	8.0-10.7
Maize silage	272-453	262-440	89-96	545-1170	11-17	2.2-3.1
Triticale silage	190-315	167-282	87-95	990-1160	13-19	1.1-4.8
Fruit marc	220-255	210-230	96-98	1120-1250	25-35	1.2-3-2
Potatoes	157-192	167-180	92-94	980-1050	20-26	2.2-3-9
Onions	103-130	96-104	91-94	880-996	20-34	3.0-3.3
Vegetables (e.g., lettuce)	40-80	31-70	80-91	765-1050	21-36	6.4-7.7



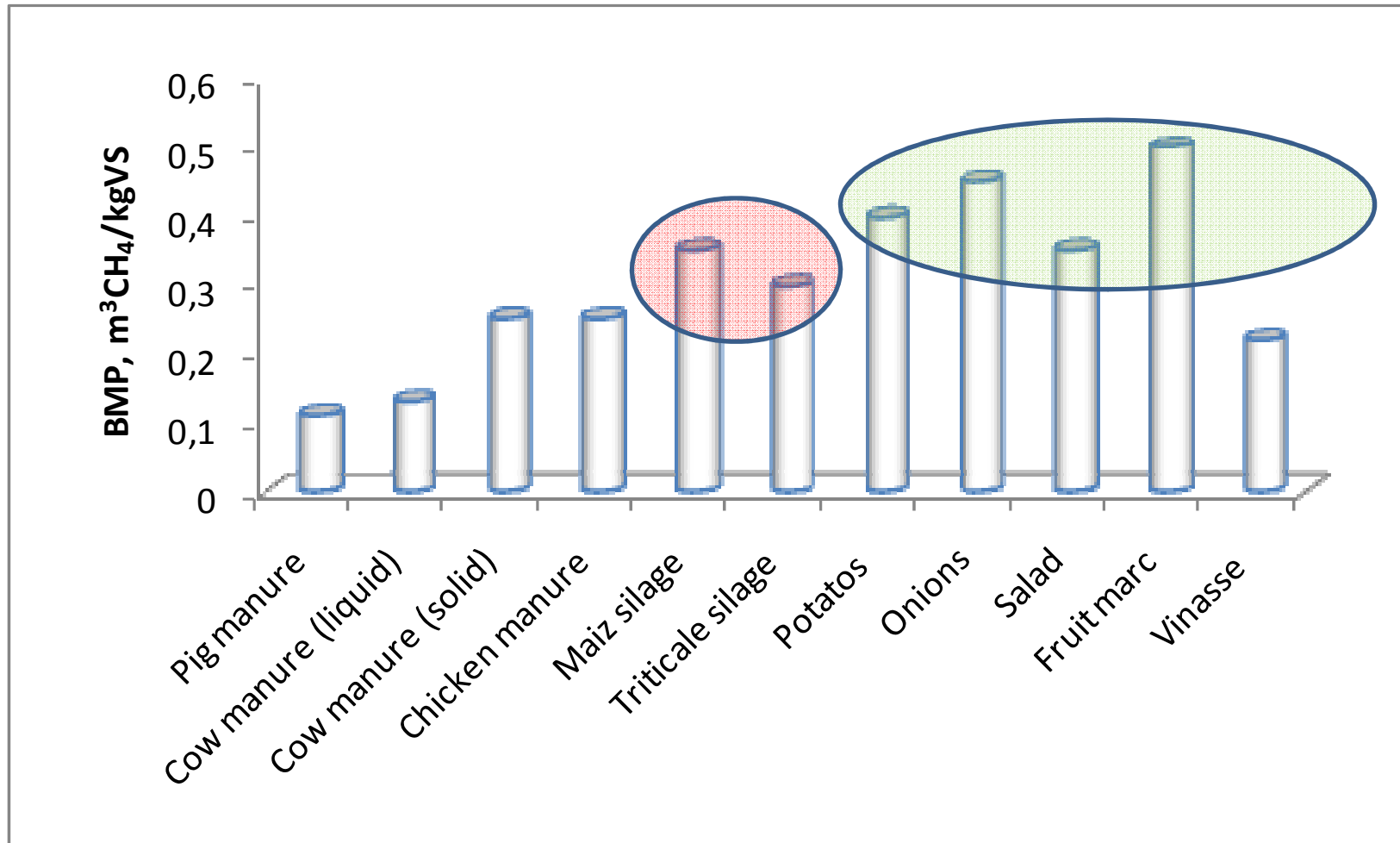
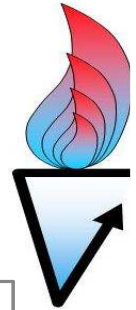


Biogas potential for different substrates



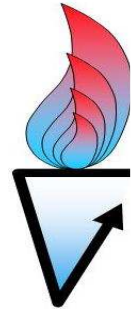


Biogas potential for different substrates





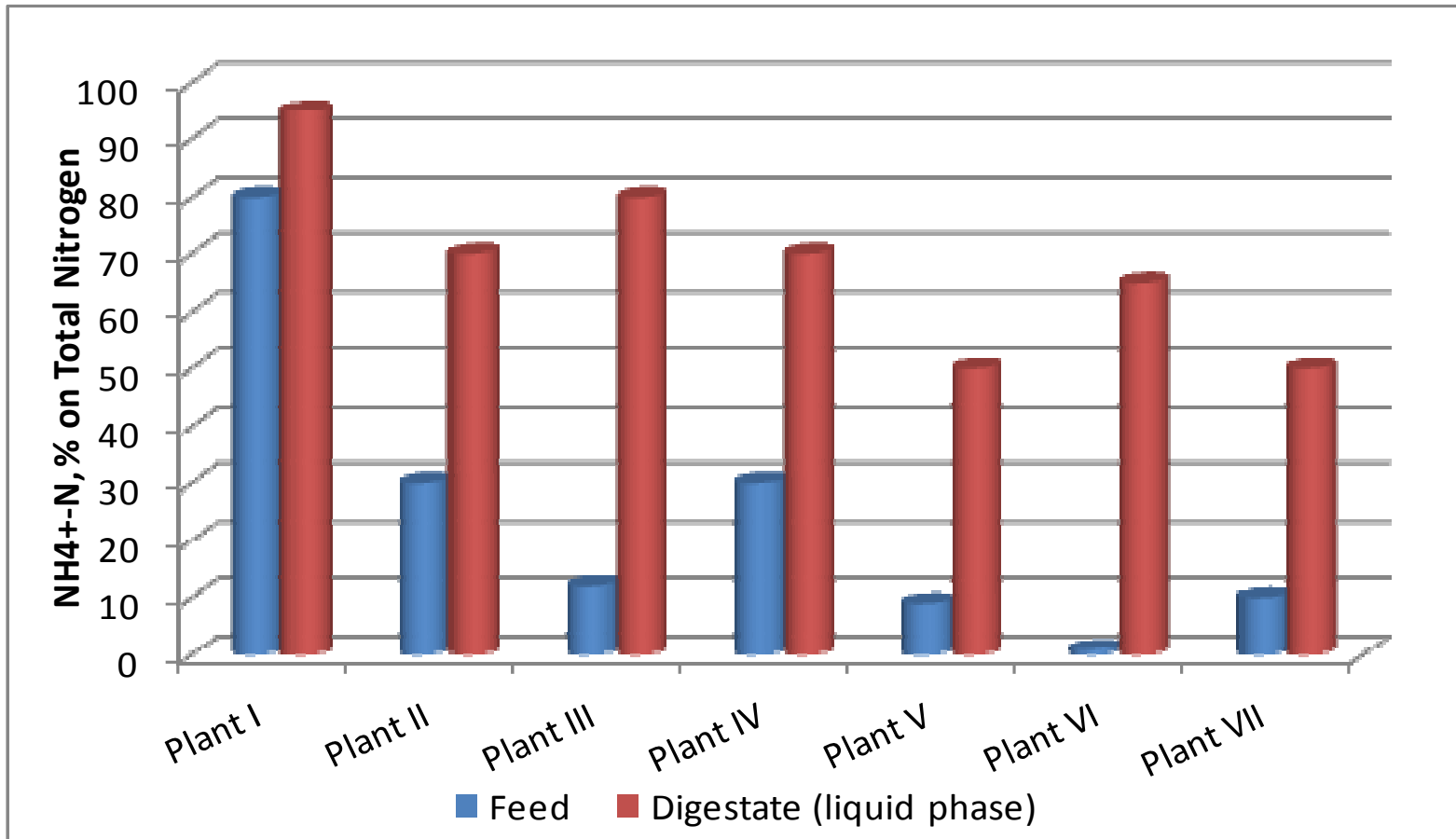
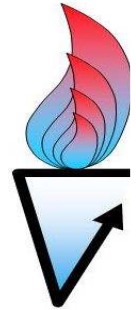
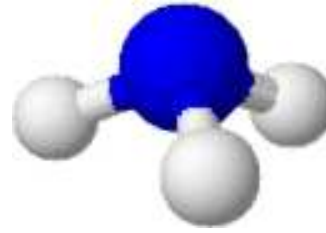
Clearly, this change also determine some changes in the plant structure and managing



- Different substrates, with different characteristics, need to be properly stored
- Feeding strategies and tools (hoppers, pumps
- Reactor mixing should be improved / changed

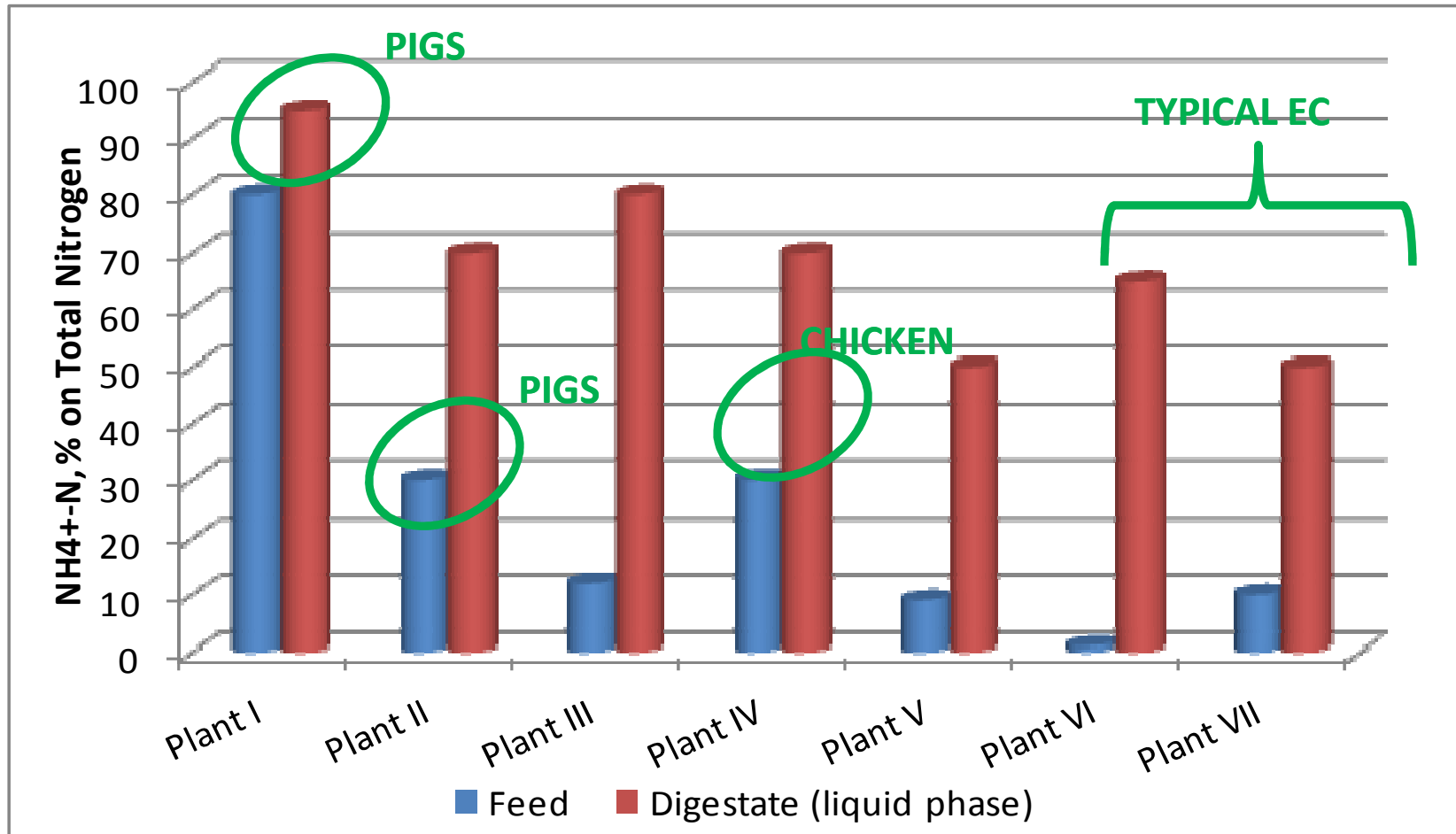
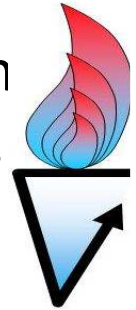


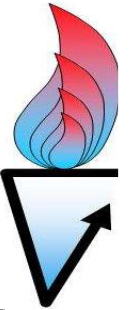
We forgot nitrogen



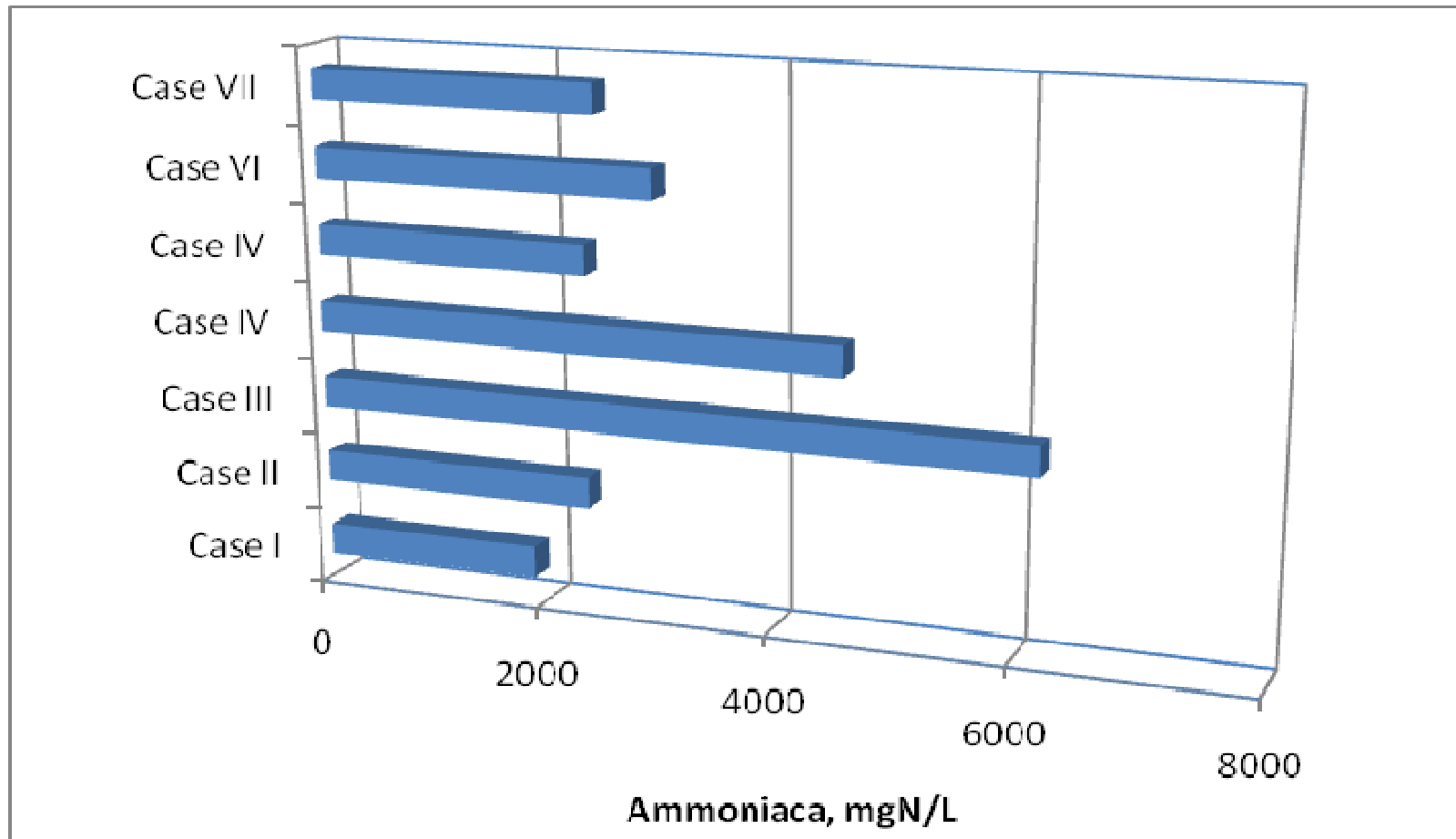


Typical nitrogen distribution in influent and effluent of Italian anaerobic digesters treating livestock effluents, energy crops and agro-waste





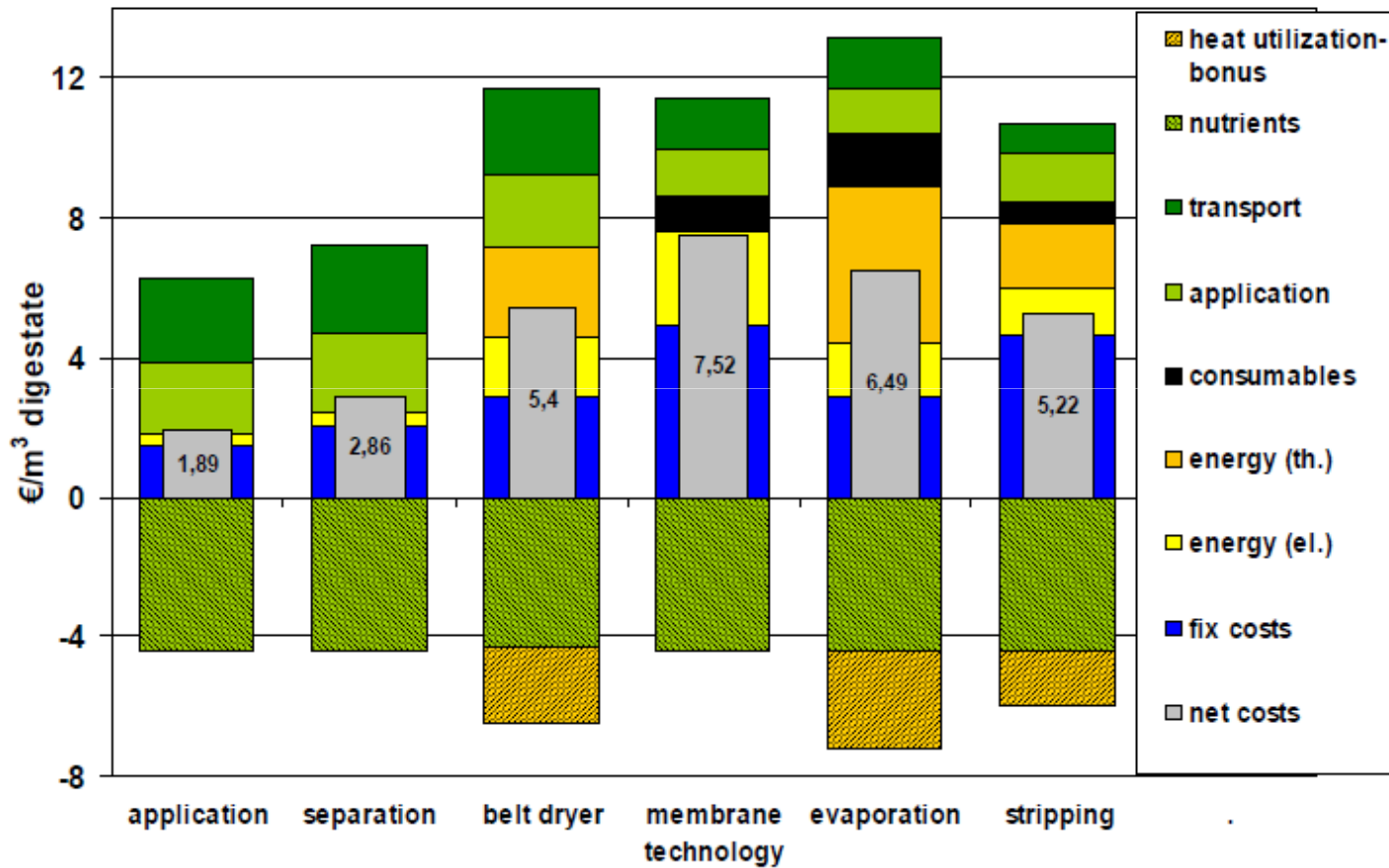
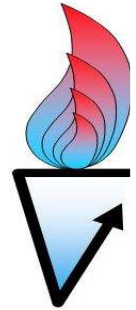
Typical levels of ammonia concentrations





Costs for nitrogen management (removal/recovery)

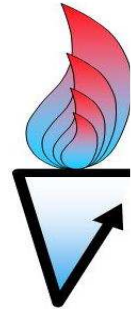
Specific costs of treatment



Wulf, IBBK Congress, Stuttgart, 2010

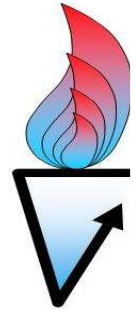
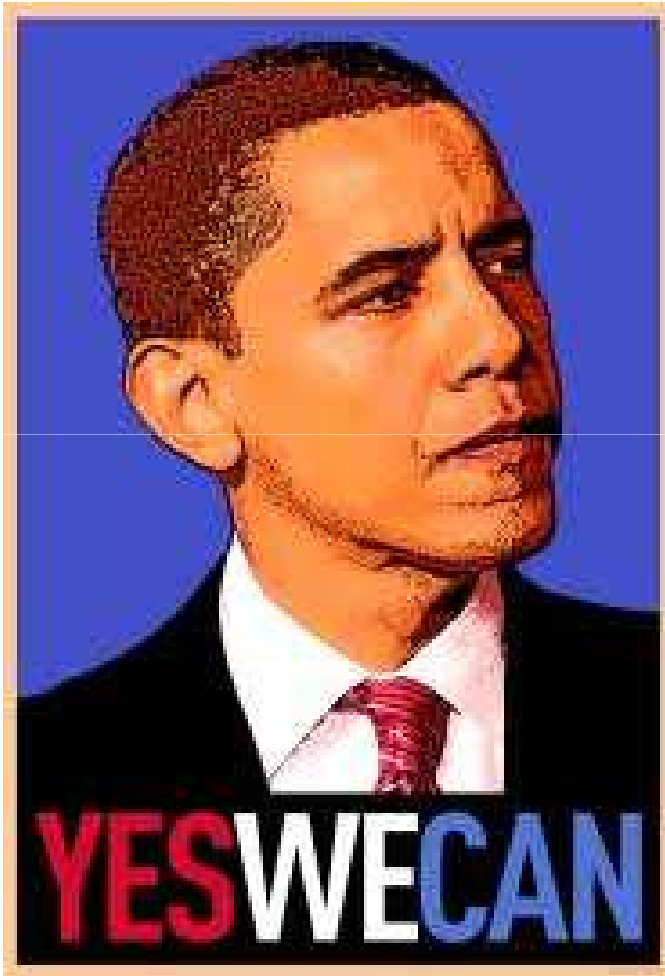


So, can we sustain this ?



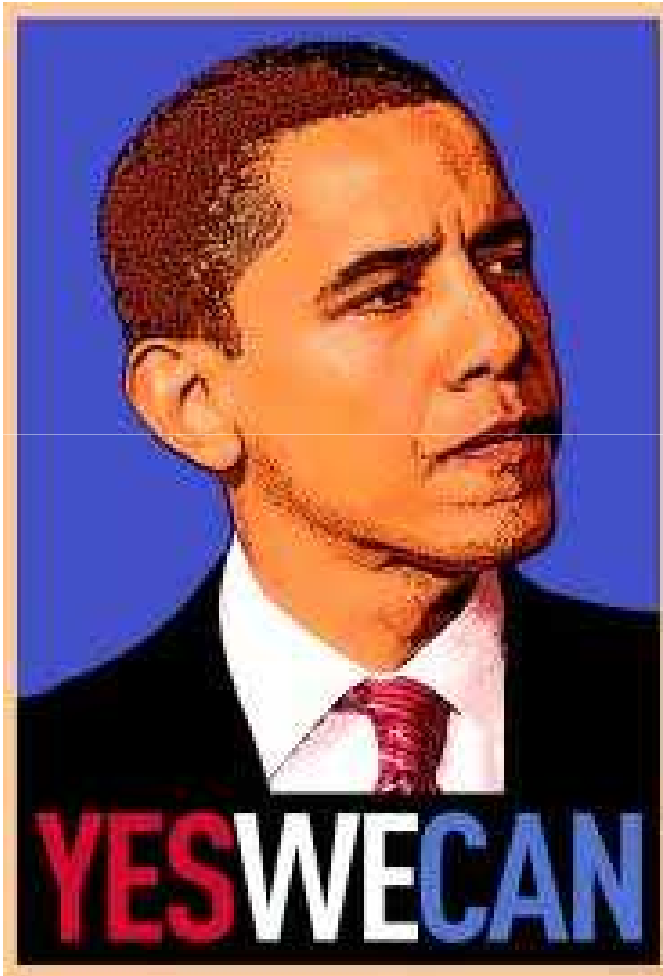


So, can we sustain this ?

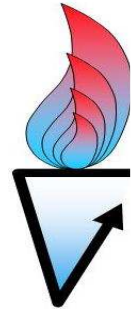




So, can we sustain this ?

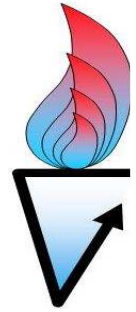


Because of the subsidy !





BASIC ECONOMIC BALANCE (1MW)

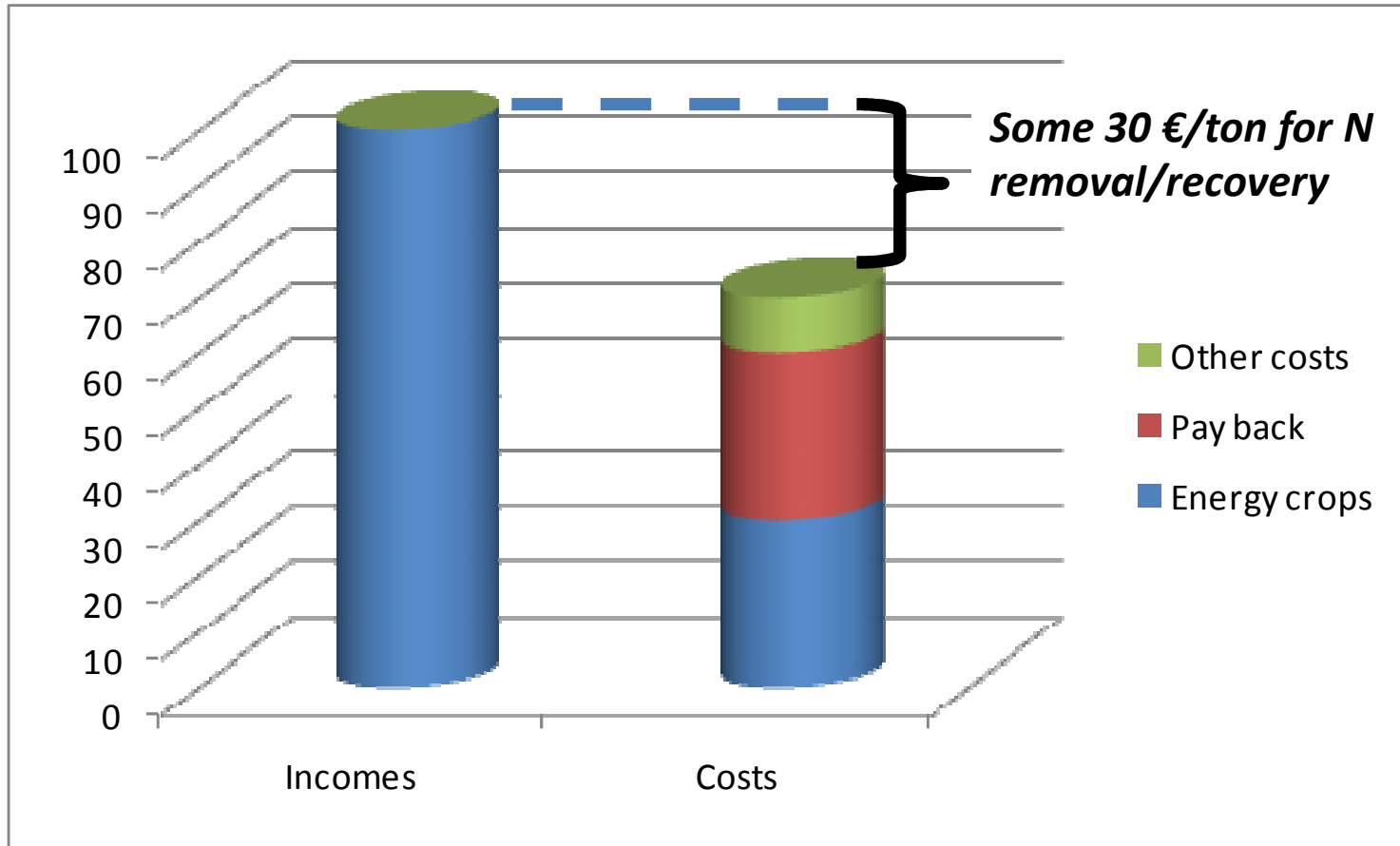
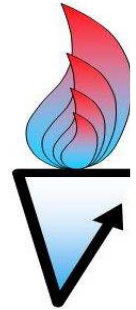


Considering the following set of data for revenues

- the biogas potential for cow manure and maize silage
- 2 kWh electric energy per m³ of biogas
- 0.28 € per kWh
- Avg income 100 € per ton fed

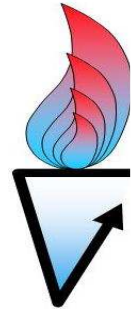
And the expenses

- 30 € per ton of maize silage
- Plant pay-back (ca. 30 €/ton)
- Other costs (ca. 10 €/ton)





And what about thermal energy?!?!
We have several things to do



Heat/cheel houshold/farms



Greenhouse heating



Swimming pools heating