A versatile technology: various approaches for anaerobic digestion

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GRUP DE RECERCA EN BIOTECNOLOGIA AMBIENTAL

Miembro de: XIT XARXA DE CENTRES DE SUPORT A LA INNOVACIÓ TECNOLÒGICA

Outline

- Aims
- Introduction
- Some historical data.
- Technologies, approaches and trends
- Co-digestion approach
- An example of codigestion
- Summary: AD flexible and versatile technnology
- Some final remarks

Outline

- Aims

To offer a global vision of what can AD do, which are the trends and opportunities of this technology

ANAEROBIC DIGESTION

Multistep process

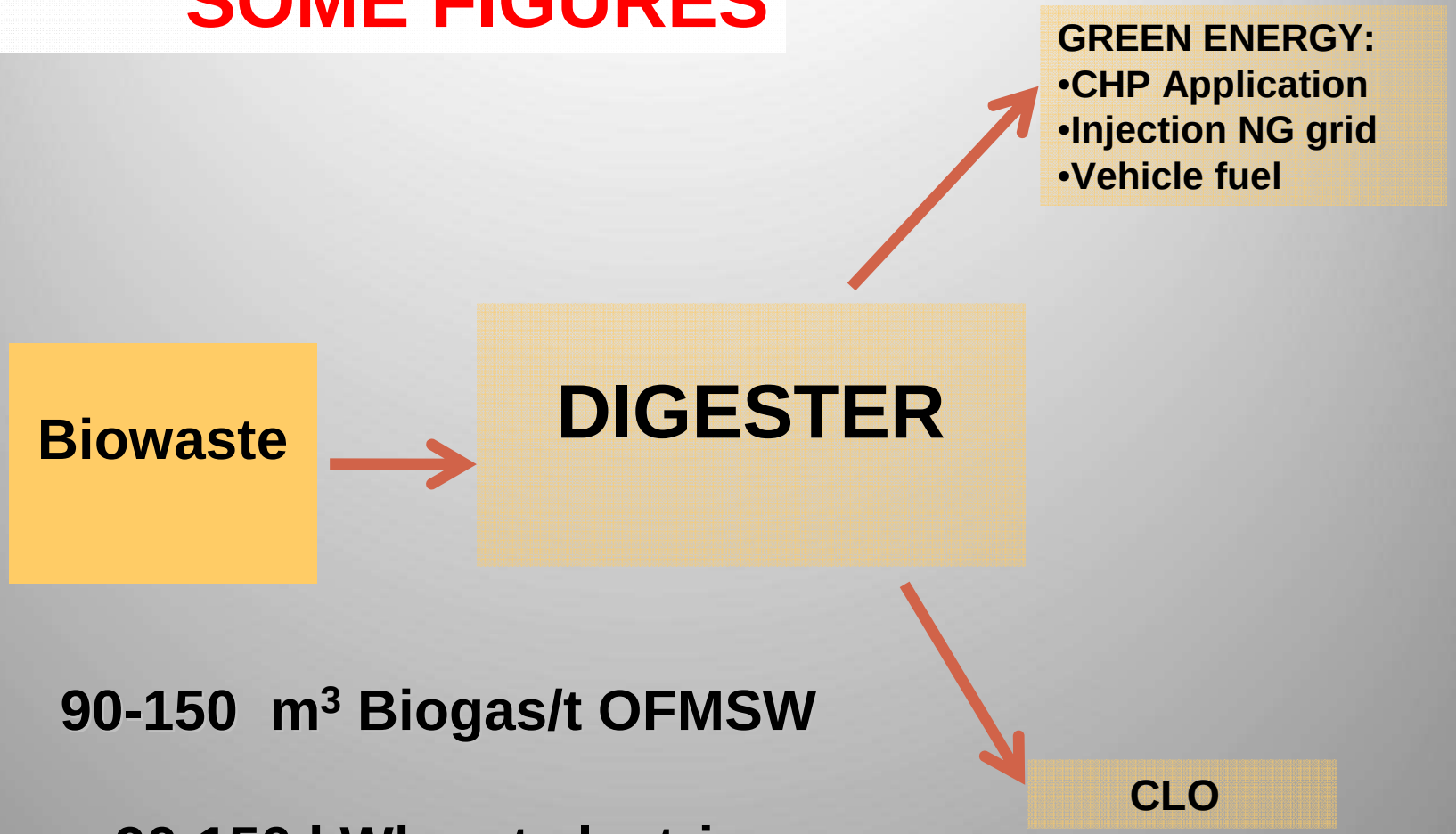
ORGANIC MATTER → BIOGAS + CEL MAT.

No external electron acceptor

65% CH_4
35% CO_2

Reduced amount

SOME FIGURES



90-150 m^3 Biogas/t OFMSW

90-150 kWh net electric. Surplus/ t OFMSW

SOME FIGURES

GREEN ENERGY:
- **CHP Application**
- **Injection NG grid**
- **Vehicle fuel**

Biowaste → **DIGESTER**

DIGESTER → **CLO**

1 m^3 Biogas: (60 % CH_4)
6 kWh
1.1 kg CO_2 emm. savings

Soil appl.: Additional savings: ca. 3 kg CO_2 emm. savings

Advantages of compost or digestate soil application related to GHG savings and other

- C sequestration
- Peat and straw subtitution (incl. transport)
- Fertilizer savings (incl. transport)
- Less irrigation requirements (better water and nutrient hoding capacity)
- Better soil structure (porosity)
- Less possibilities of soil erosion

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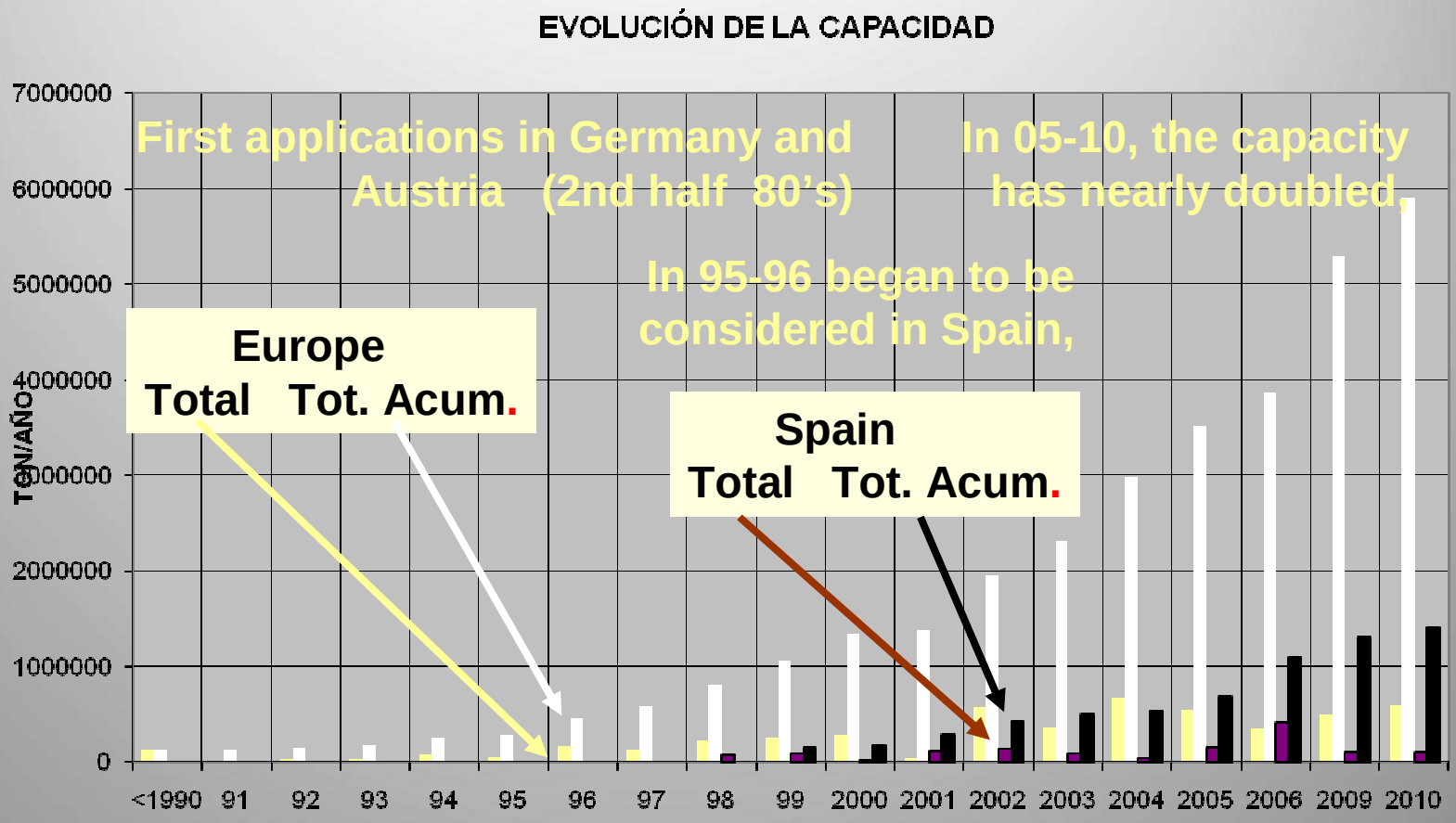
- **Some historical and trend data**

Evolution of the installed capacity in Europe and Spain



(De Baere, Wat. Sci &Tech. 57 (7) 2008 and own data)

Evolution of the installed capacity in Europe and Spain

- The overall installed capacity of OFMSW – AD in Europe is around 6 million ton/year, half of which are treating biowaste.
- However it is still a small share compared with the total MSW produced in Europe or with the installed incineration capacity (more than 8 times higher).

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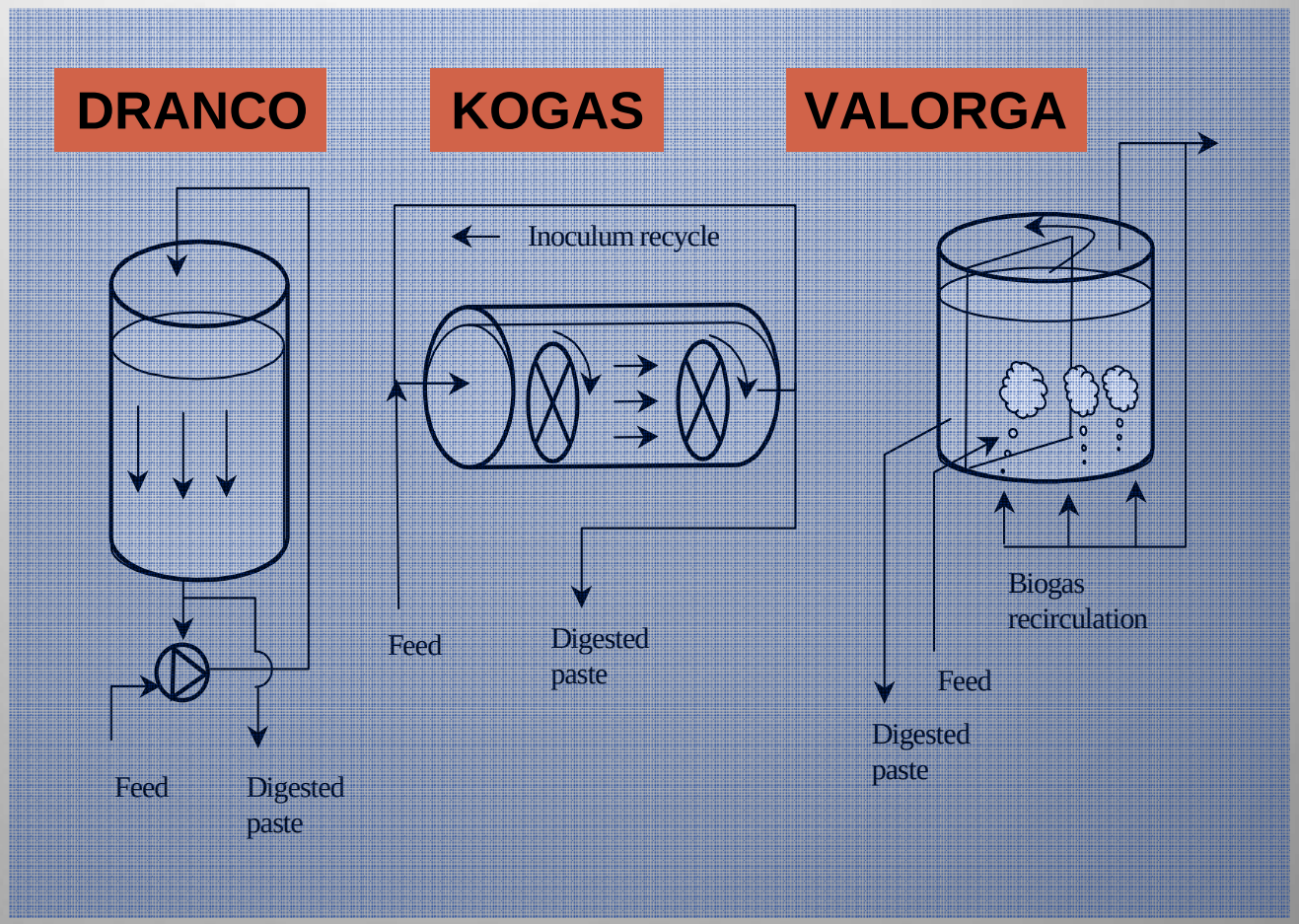
- **Technologies for AD and approaches**

TECHNOLOGIES: Classification

SUBSTRATE FED	TEMPER.	USE OF BIOGAS	MODE OF OPERATION
Biowaste	Mesophilic	CHP	Batch
Residual waste	Thermophilic	Grid Injection	Continuous
Cosubstrates	Psycrophilic	Vehicle Fuel	

FLOW PATTERN	NUMBER OF STEPS	SOLID CONTENTS	DIGESTATE TREATM.
Plug flow	Single	Dry	No treat.
Mixed	Two-steps	Wet	Composting

PLUG-FLOW DIGESTERS



(Vandevivere et al., 2003)

TECHNOLOGIES: Dry/Wet

- “Dry” technology is simpler (less pre-treatment and less water involved)
- Recirculation is needed to assure adequate inoculation of the feed.

- Presently, more than 60% of the installed capacity is using “dry digestion”
- The trend seems to be using dry technology.

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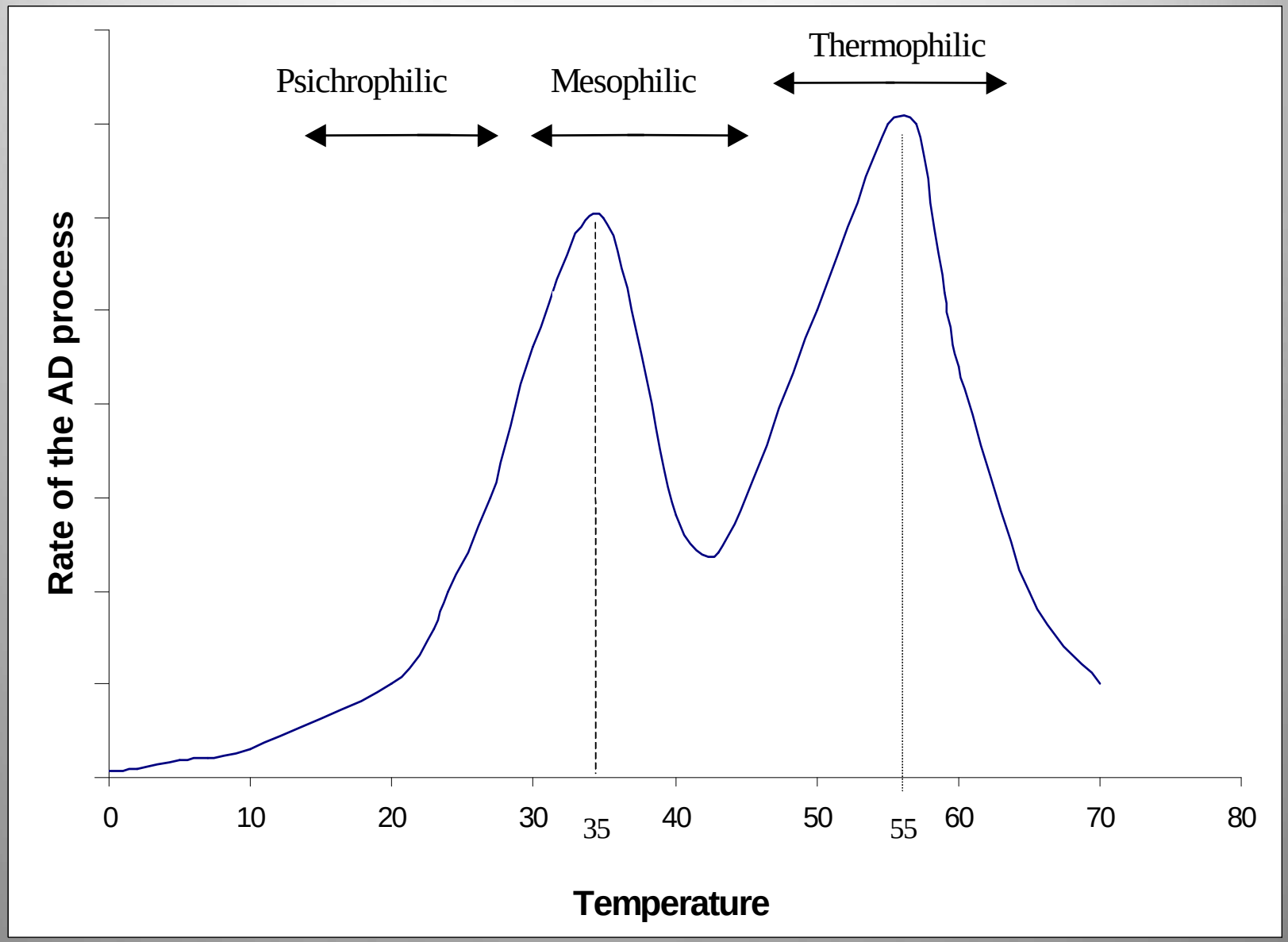
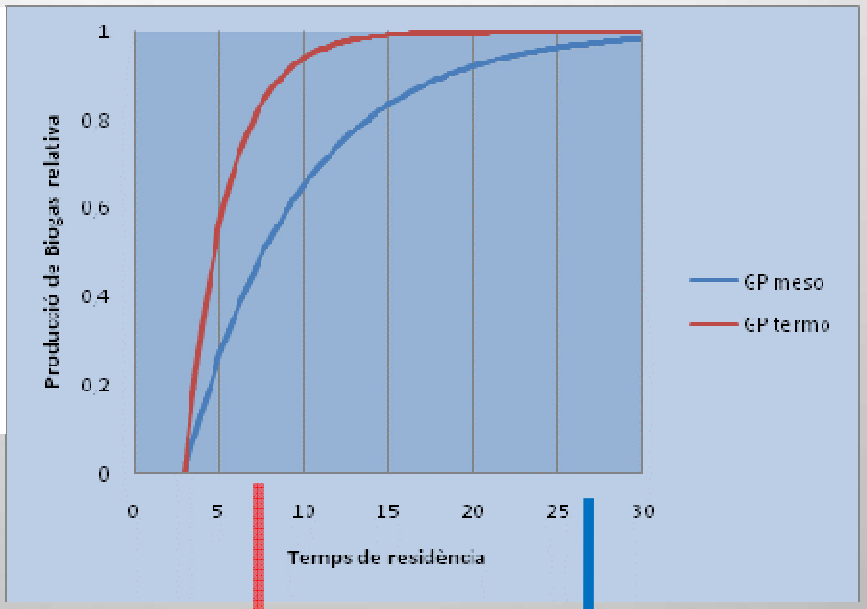
Temperature ranges of operation



Thermofilic vs. Mesophilic AD

Around 70% of the present installed capacity in Europe is mesophilic
Trend: Stable during the last years.



At low HRT, TAD gives better yields

At high HRT, yields are similar

Specific values depend on the specific substrate

Supernatant with more VFA content

Full scale results Meso vs. Thermo	Full scale mesophilic	Full scale thermophilic
OLR, kgTVS/m^{3}d	**1,62**	**1,28**
SGP, m^3/kgTVSa	**0,35**	**0,55**
GPR, m^3/m^{3}d	**0,56**	**0,70**
pH	**7,2**	**7,6**
TA(pH 6), mgCaCO$_3$/l	**1073**	**1444**
VFA, mgCOD/l	**270,1**	**267,8**
NH$_3$, gN/l	**0,42**	**0,69**

(Pavan et al., 2008)

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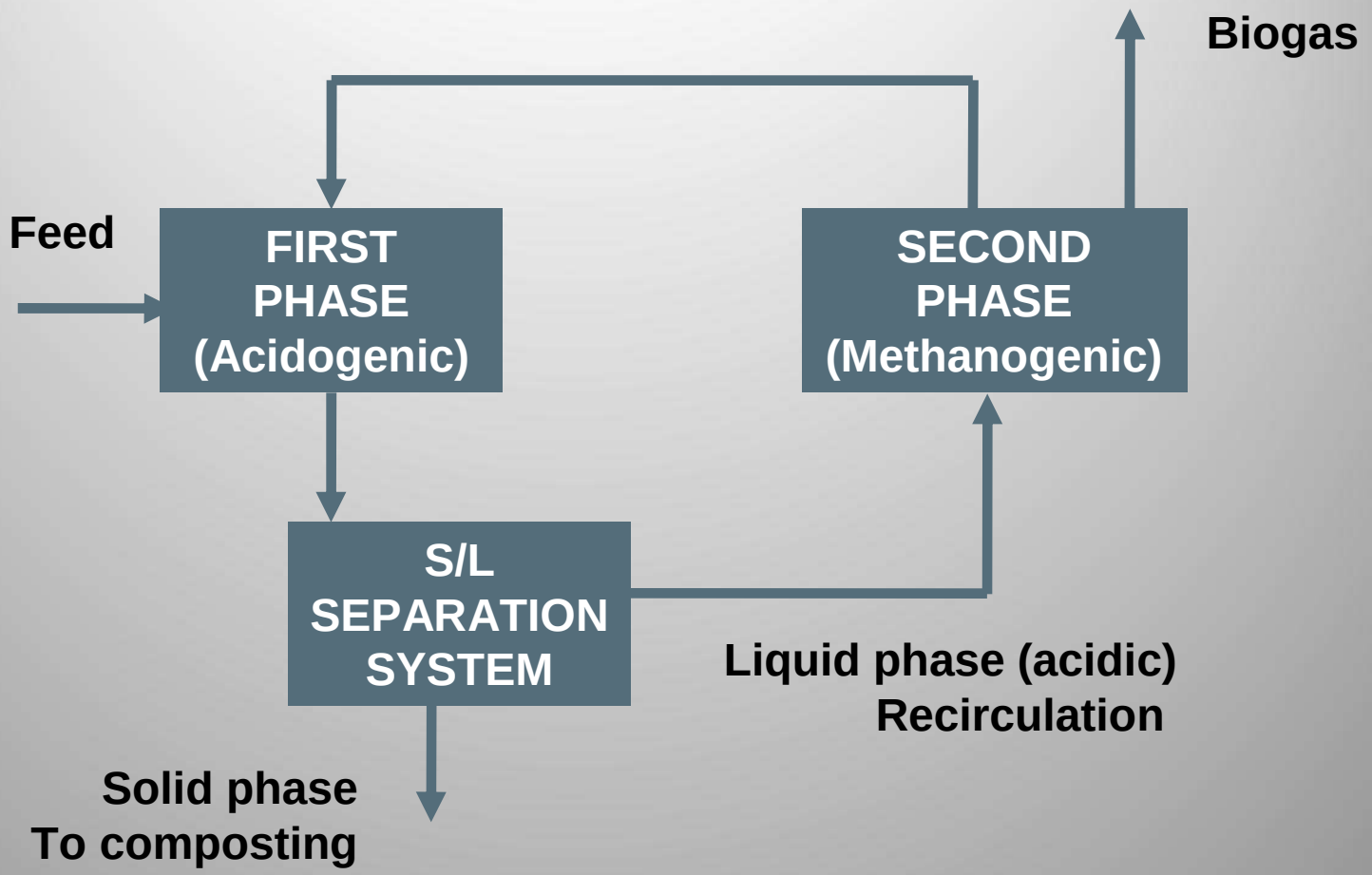
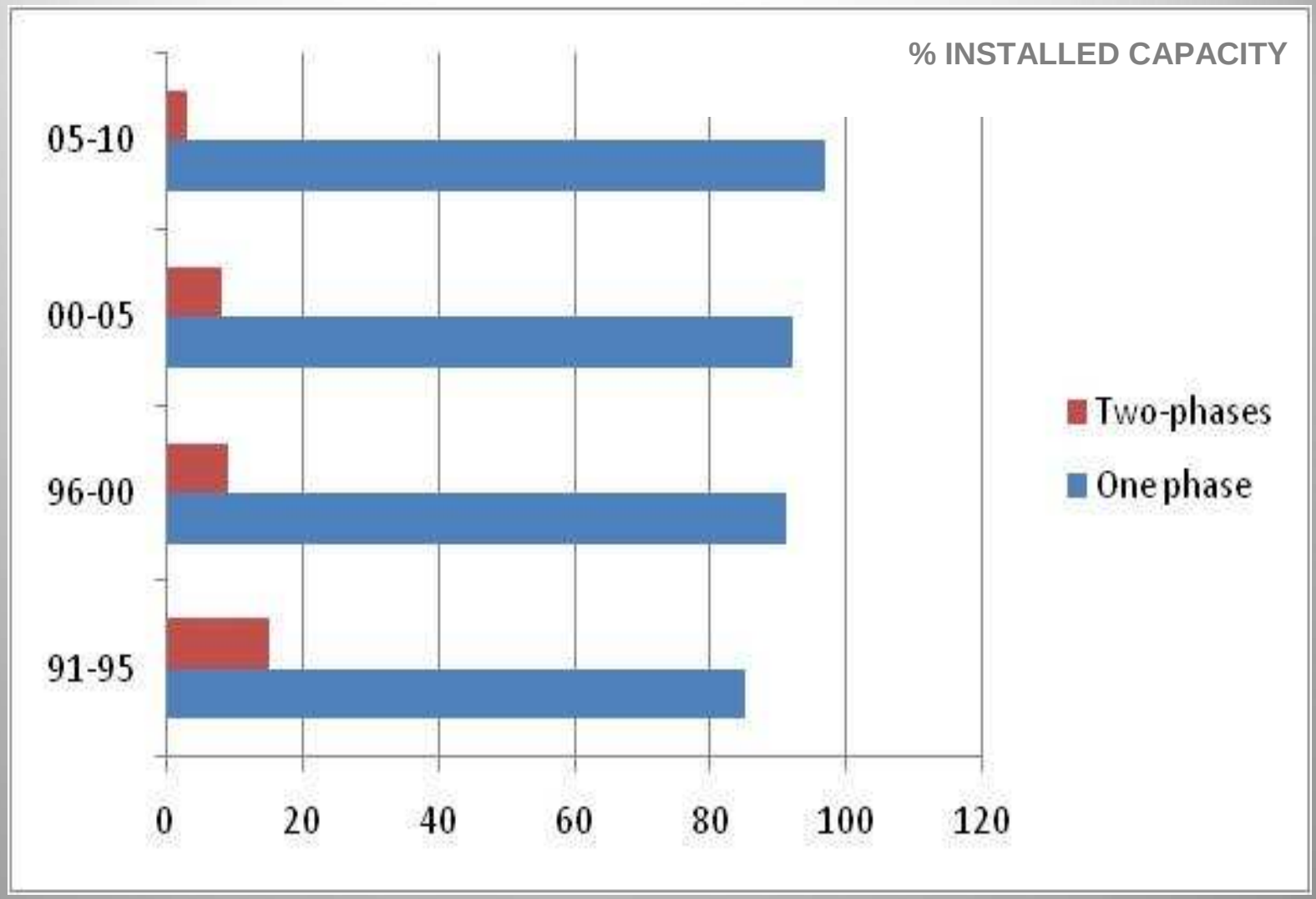
TWO PHASE SIMPLE FLOW-SHEET





2010: 5,5 Mt in 1-step system vs.
0,4 Mt in 2-steps system

(DeBaere, 2010)

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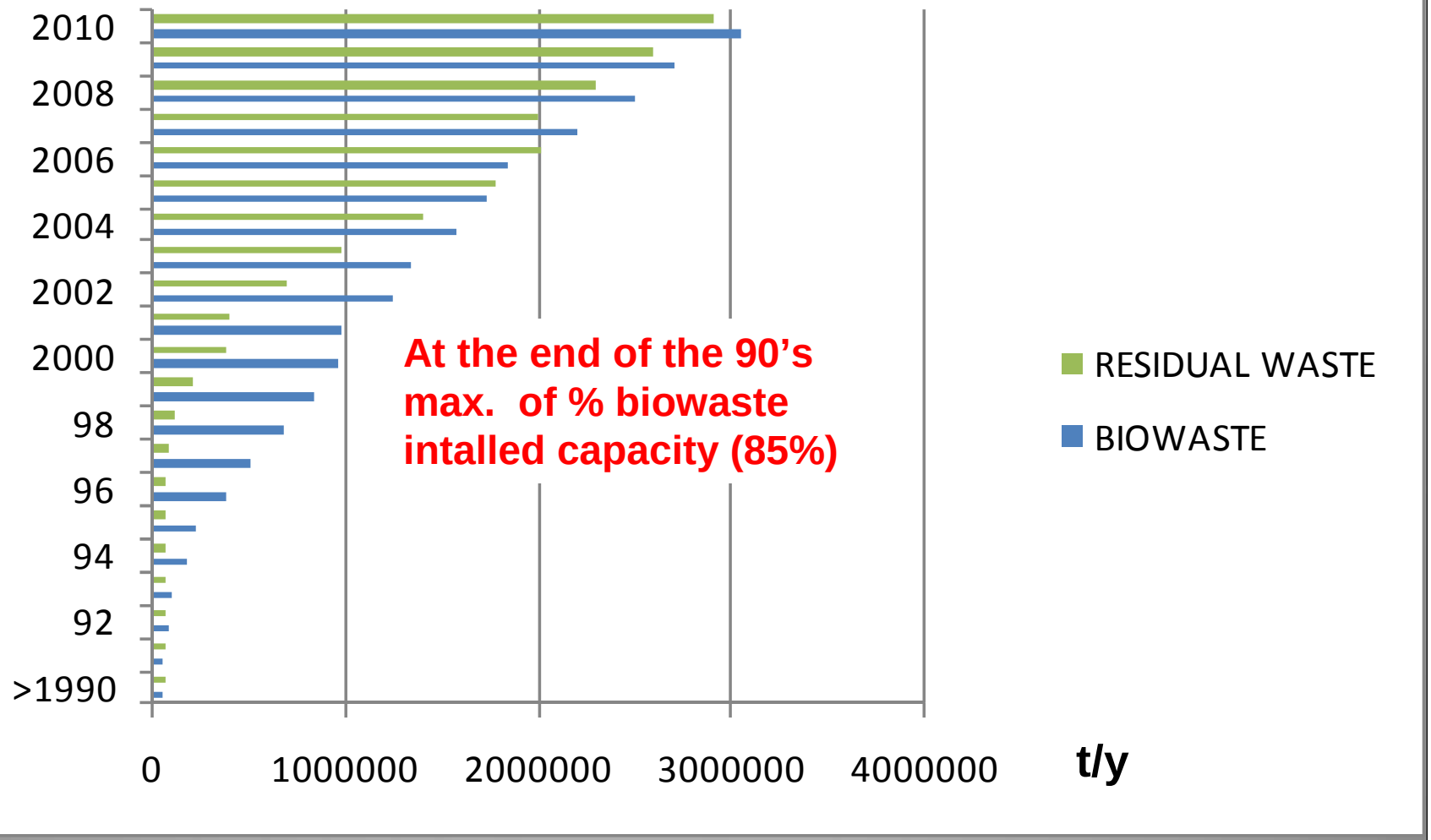

Trend: Same percentages of biowaste and residual waste

(DeBaere, 2010)

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The codigestion approach

Biowaste AD approaches:

- **Co-digestion:**
  - **Sewage Sludge**
  - **Agricultural wastes**
  - **Farm wastes**
  - **Agroindustrial Wastes.**
  - **Food markets**
  - **etc**

Codigestion consists in the digestion of a mixture of two or more substrates with complementary characteristics so that to enhance biogas production.

SUBSTRATE A

- C/N Ratio
- Macro-micronutrients
- pH
- Alkalinity
- Inhibitors/toxic
- Biodegradable OM
- Water content

SUBSTRATE B

ANAEROBIC CO-DIGESTION

Co-digestion is an interesting option for improving yield of anaerobic digestion of wastes.

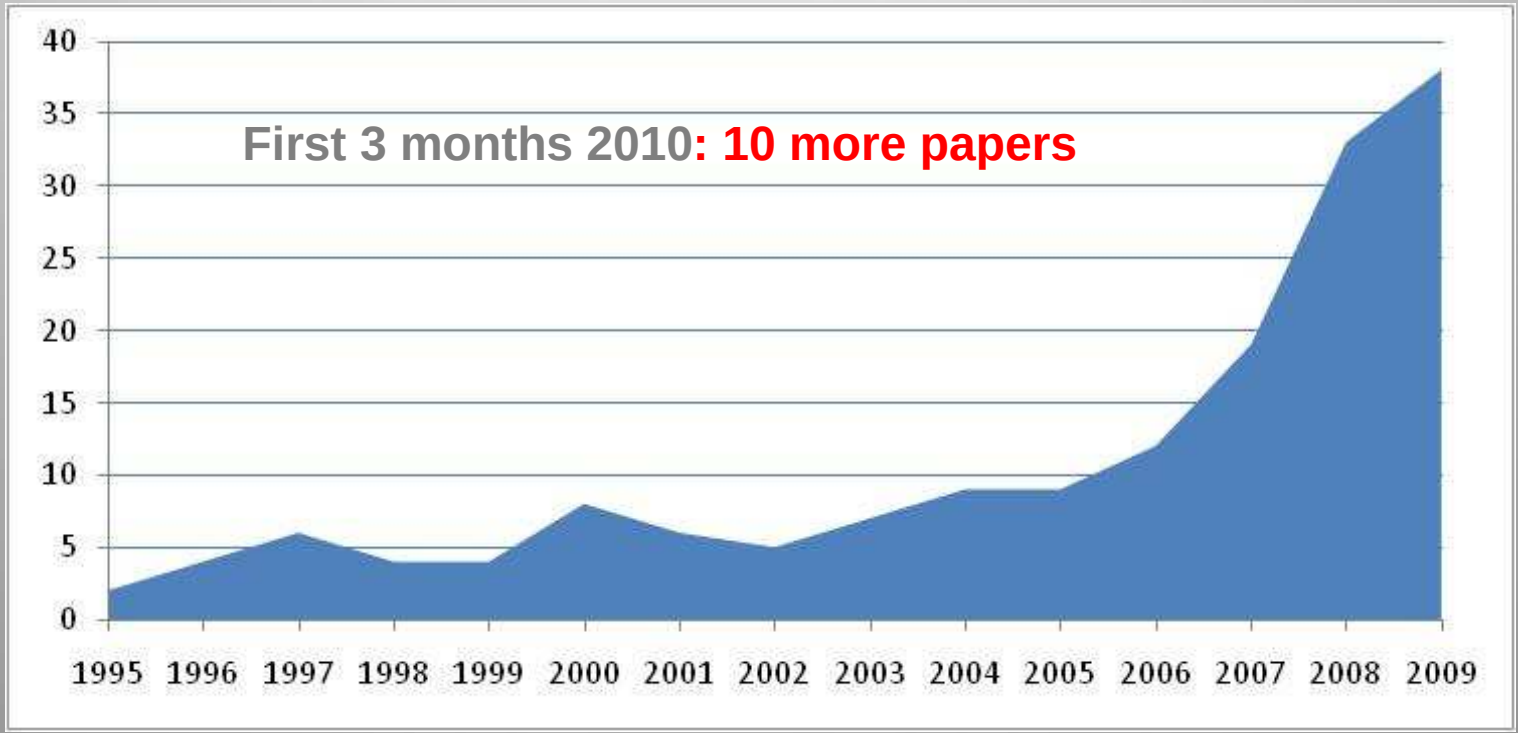
2 + 2 = 5

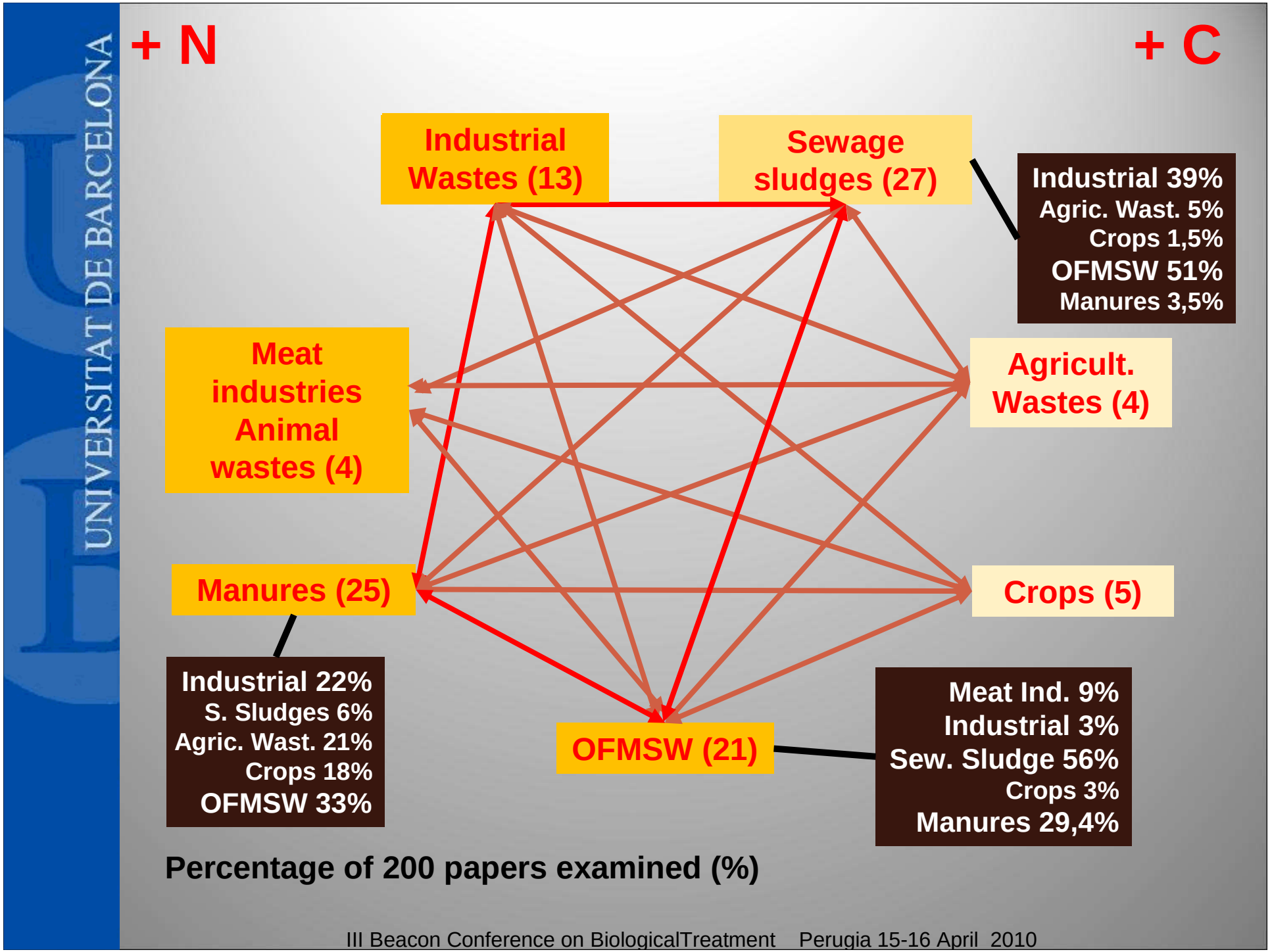
CO-DIGESTION:

- **Positive synergisms established in the digestion medium.**
  - ✓ **The co-substrate supplies missing nutrients in the substrate.**
  - ✓ **Increase organic content inside the reactor**
  - ✓ **Enhance the digestate estabilization**
  - ✓ **Dilution of potential inhibitory and/or toxic compounds.**

CO-DIGESTION: Hot topic in AD

Co-digestion: More than 40% of the papers dealing with co-digestion were published in 2008 and 2009.




+ N
+ C
Industrial Wastes (13)
Sewage sludges (27)
Industrial 39%
Agric. Wast. 5%
Crops 1,5%
OFMSW 51%
Manures 3,5%
Meat industries Animal wastes (4)
Agricult. Wastes (4)
Manures (25)
Crops (5)
Industrial 22%
S. Sludges 6%
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Meat Ind. 9%
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Sew. Sludge 56%
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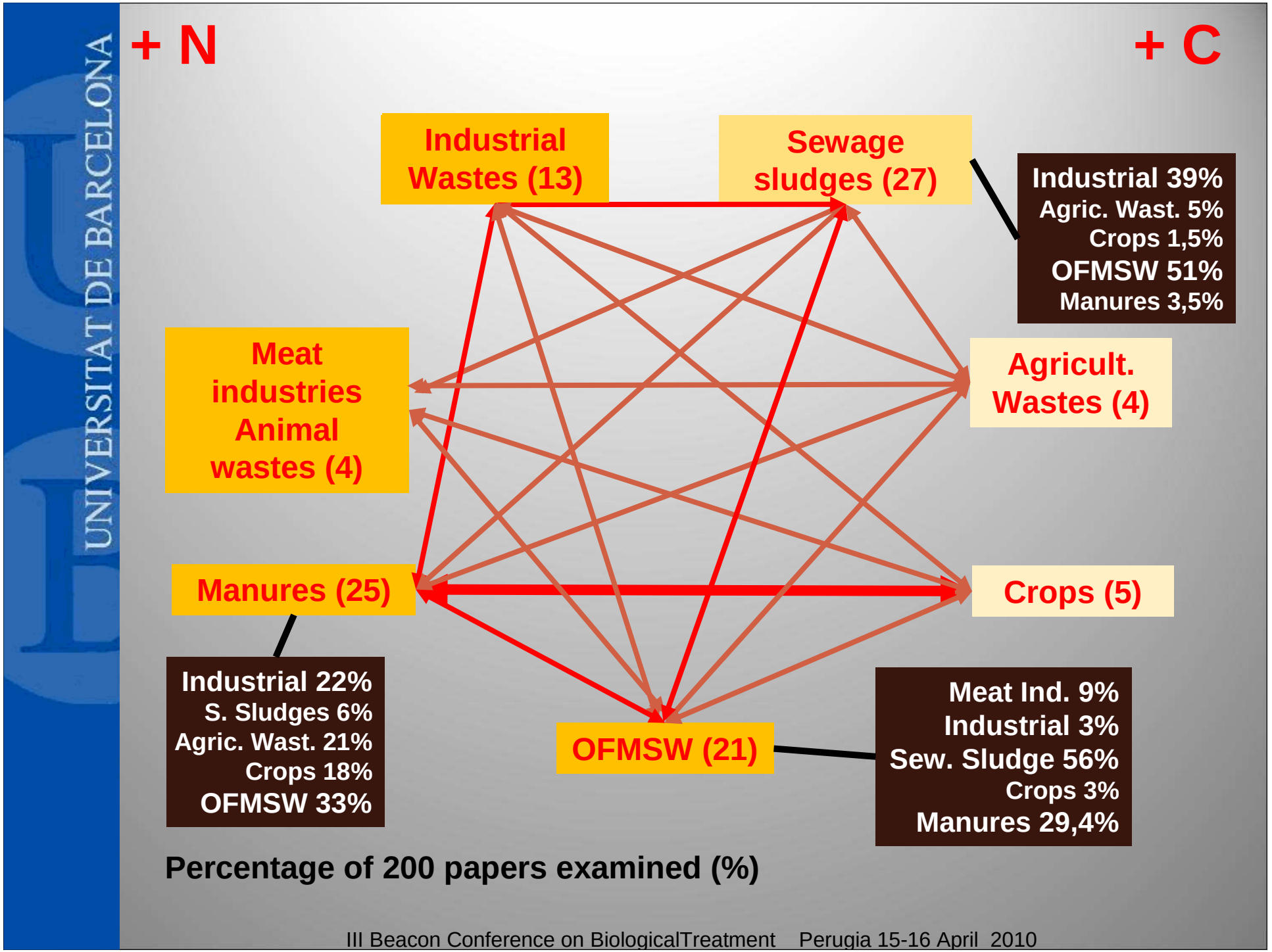
Manures 29,4%
Percentage of 200 papers examined (%)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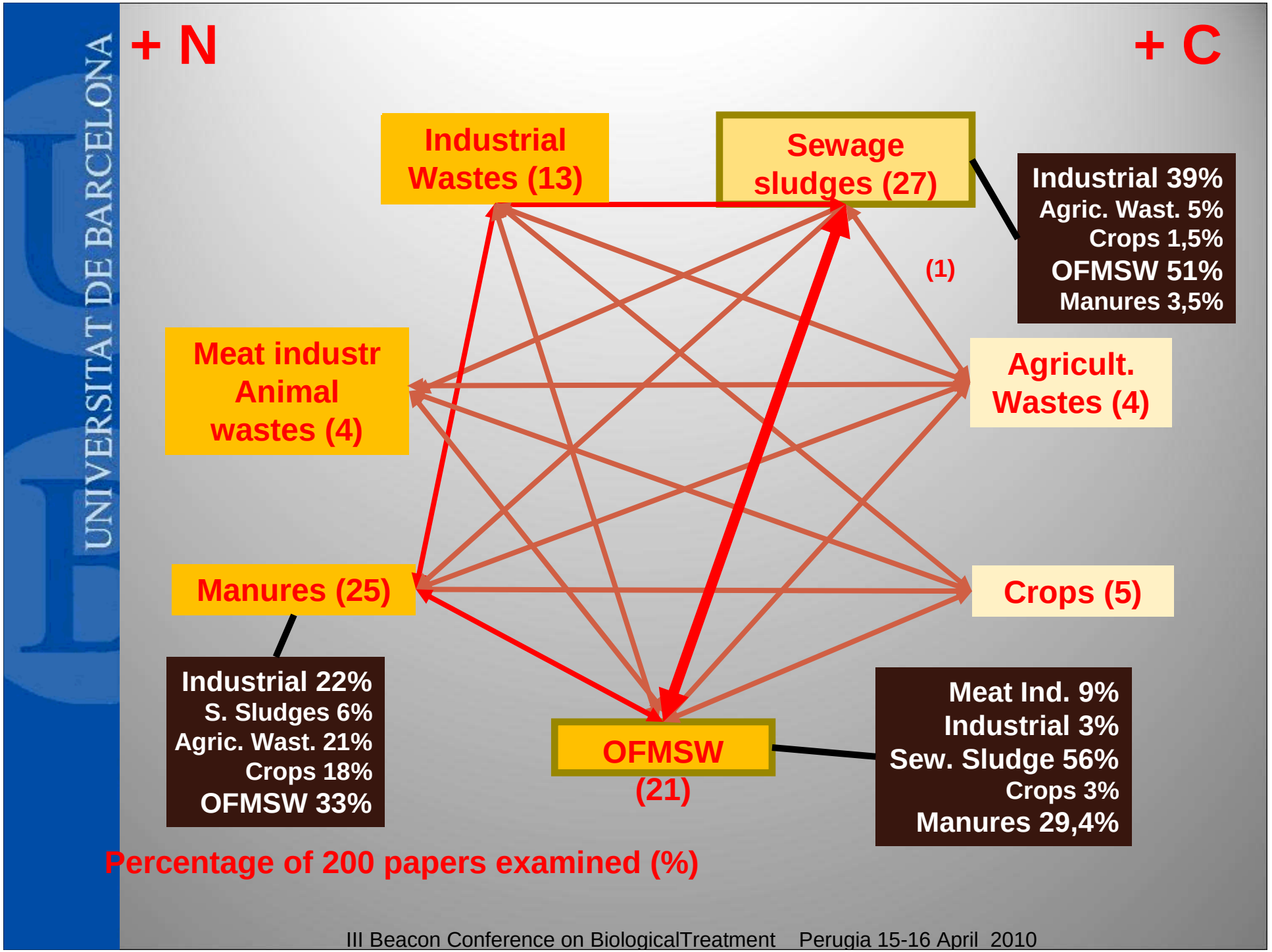
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- Co-digestion of OFMSW and Sewage Sludge (SS) is an old topic. Early references are on the seventies – eighties (Ghosh and Klass, 1976; Hitte (1976) or Diaz et al. (1980).
- Co-digestion process can be successfully implemented in existing WWTPs to improve the digester performances, thus the energetic balances and GHG emissions.

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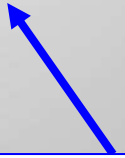
Codigestion Possibilities

BIOWASTE in WWTP

Biowaste AD plant
+ SS



- **Interesting (uses already existing infrastructures)**
- **Loading rate Digesters low**

Common in some plants

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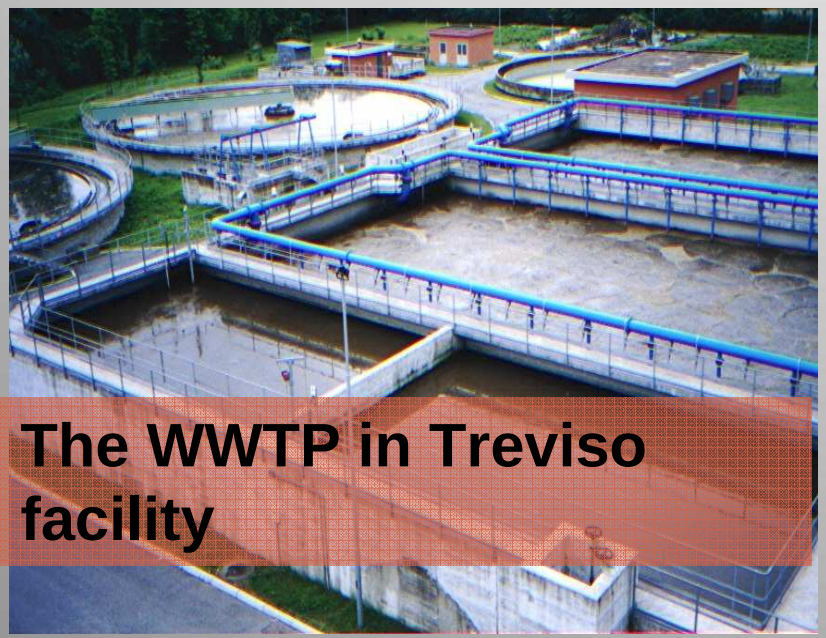
- **An example of co-digestion**

The Treviso facility

Modified Johannesburg configuration **70.000 EI**
WW flow-rate: 24000 m^3/d
OFMSW inlet: 20 t/d



The WWTP in Treviso facility

(Cecchi et al., 1994; Pavan et al. 1998, 2000)

The Treviso facility

Ratio SS/OFMSW VS: 40/60
OLR finally applied: 0.78 kg VS/m^3.d

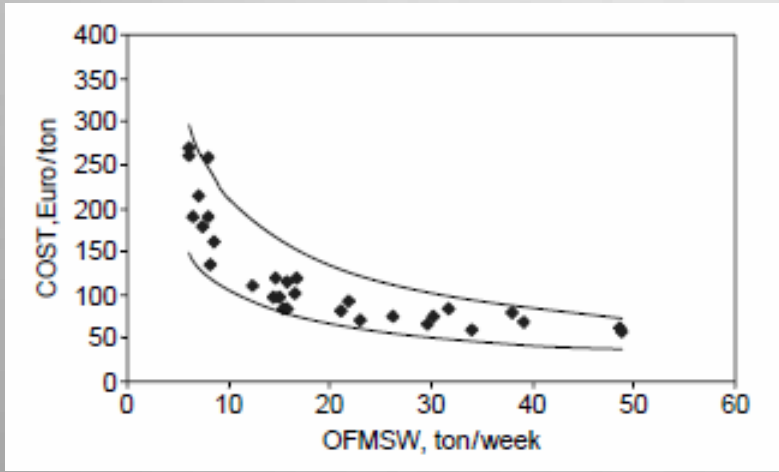
GP was increased by a factor of 3.4

Parameter	Sludge only	Co-digestion
HRT, d	37.2	35.6
OLR, kgTVS/m3 d	0.53	0.78
TS, g/Kg	36.0	41.0
TVS, %TS	62	67
GPR, m3/m3 d	0.10	0.34
SGP, m3/kgTVS	0.13	0.43
pH	6.90	7.2
TA(4), mgCaCO3/l	1865	3058

The Treviso facility

Co-digestion economics (Bolzonella et al. 2006)

Investment required: 1.5 Million €
Cost of treatment OFMSW: 50€/t



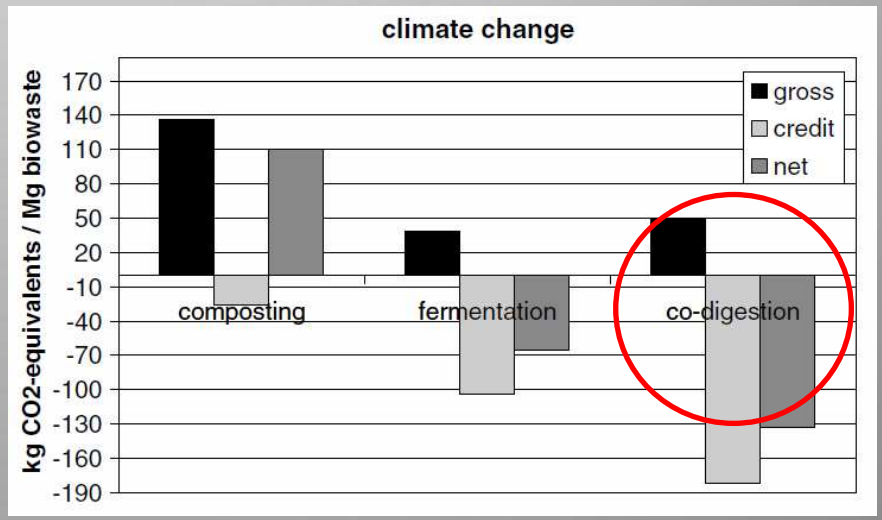
Payback time of 3.5 years.

70.000 EI
WW flow-rate: 24000 m^3/d
OFMSW inlet: 20 t/d

EXAMPLE II: Wiesbaden

A feasibility study of codigesting OFMSW and SS was conducted in two WWTP in Wiesbaden, Germany, where extra capacity is available (Krupp et al., 2005).

In this detailed study it was concluded the economical and ecological advantages of co-digestion if implemented in the large plant (350.000 EI) where no changes to the plant design were needed.



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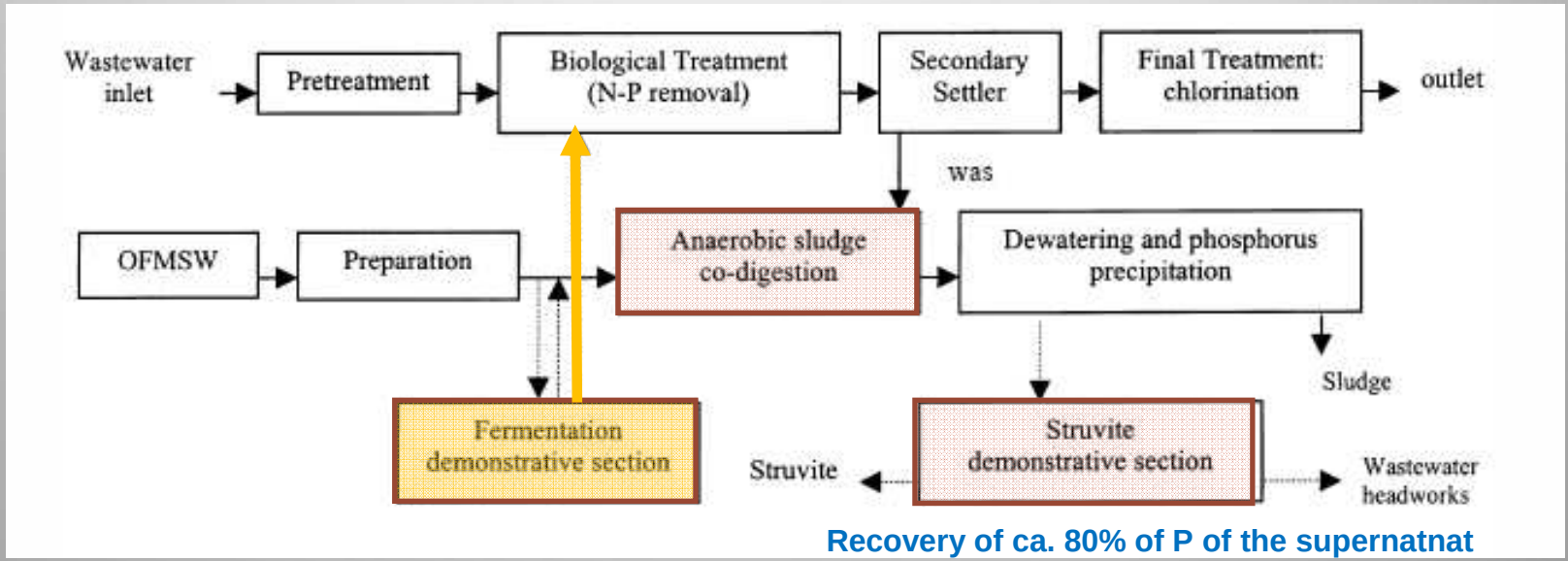

Recovery of ca. 80% of P of the supernatnat

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- **Summary AD a Flexible and versatile technology**

FLEXIBILITY AND VERSATILITY OF AD TECHNOLOGY

DIFERENT RANGES OF:	Uses of biogas	CHP. Injection to the network (vehicle fuel)
	Temperatures	Psycro, Meso, Thermo
	Moistures	From liquid to solids (wet and dry)
	Substrates	From liquid to solids Industrial, agricultural muinicipal
	Organic Loading Rates (OLR)	Up to 15 kg VS/m^3.d.

Ranges of applications

	Agricultural	Industrial	Municipal
SOLID	Wastes, crops	Agro-food industries	OFMSW
SEMI –SOLID (SLURRIES)	Manure slurries	Several industries	Sewage Sludge
LIQUID	Liquid manures	Several industries	Raw sewage

Ranges of applications

	Agricultural	Industrial	Municipal
SOLID	Wastes, crops	Agro-food	OFMSW
SEMI –SOLID (SLURRIES)			Sewage Sludge
LIQUID	Liquied manures	Several industries	**Raw sewage**

Membrane anaerobic bioreactors (MABR)
At psycophilic conditions
Add.: Reduced SS

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- **Some final remarks**

Some final remarks

- AD is a mature technology for treating biowaste, after almost 30 years of experiences.
- Similar to other technologies, plants shows economical and or operational problems
- Even the drawbacks related to higher investment costs, AD is a growing technology in all its applications, due to its advantages related to energy and GHG emission issues

- Regarding technologies related to OFMSW no general rules can be given, as each case has its optimal approach.
- For residual waste, the trend seems to be the use of dry digestion
- Mesophilic is the preferred range, even the advantages of themophilic range. Heat transmission problems can be a reason for its use in residual waste.
- Attention should be paid to the opportunities posed by codigestion to reduce costs and emissions.

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- There is a large number of over-dimensioned agricultural as well as WWTP digesters that can be improved with a very low investment by the co-digestion option. The ROI period is usually low and with the energy /climate change the perspectives seems to be good.
- Co-digestion offers also a large potential also for BNR in WWTP

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Thank you for your kind attention!

Grazie per la sua cortese attenzione!

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