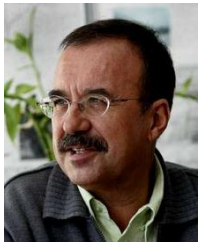
Advances in anaerobic digestion for waste valorization: **ANAEROBIC CODIGESTION** control & substrate blending

Jorge **Rodríguez**

Santiago **García-Gen**



Juan M. **Lema**

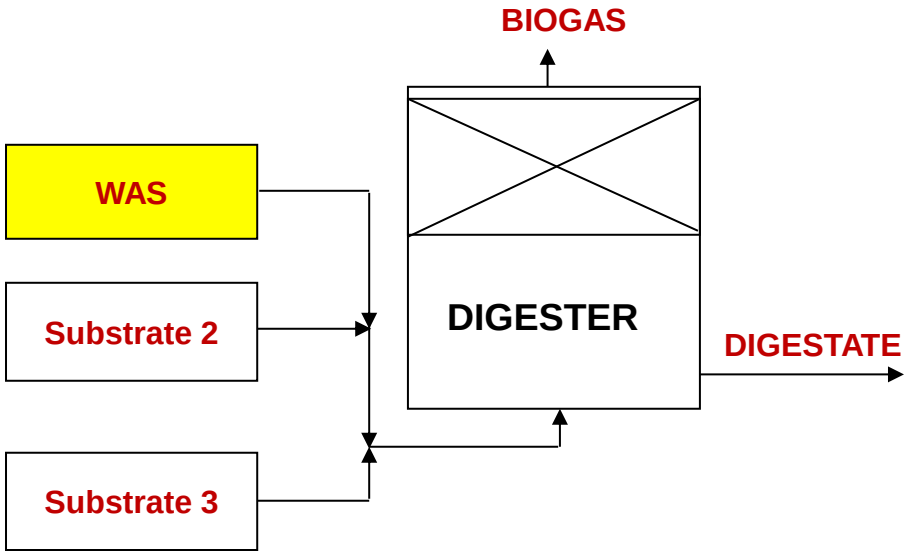
Anaerobic Co-digestion

What is Anaerobic Co-digestion?

Simultaneous AD of a homogenous blend of two or more organic substrates

Organic Matter + BIOMASS → CH_4+ CO_2 + BIOMASS + ORGANIC MATTER

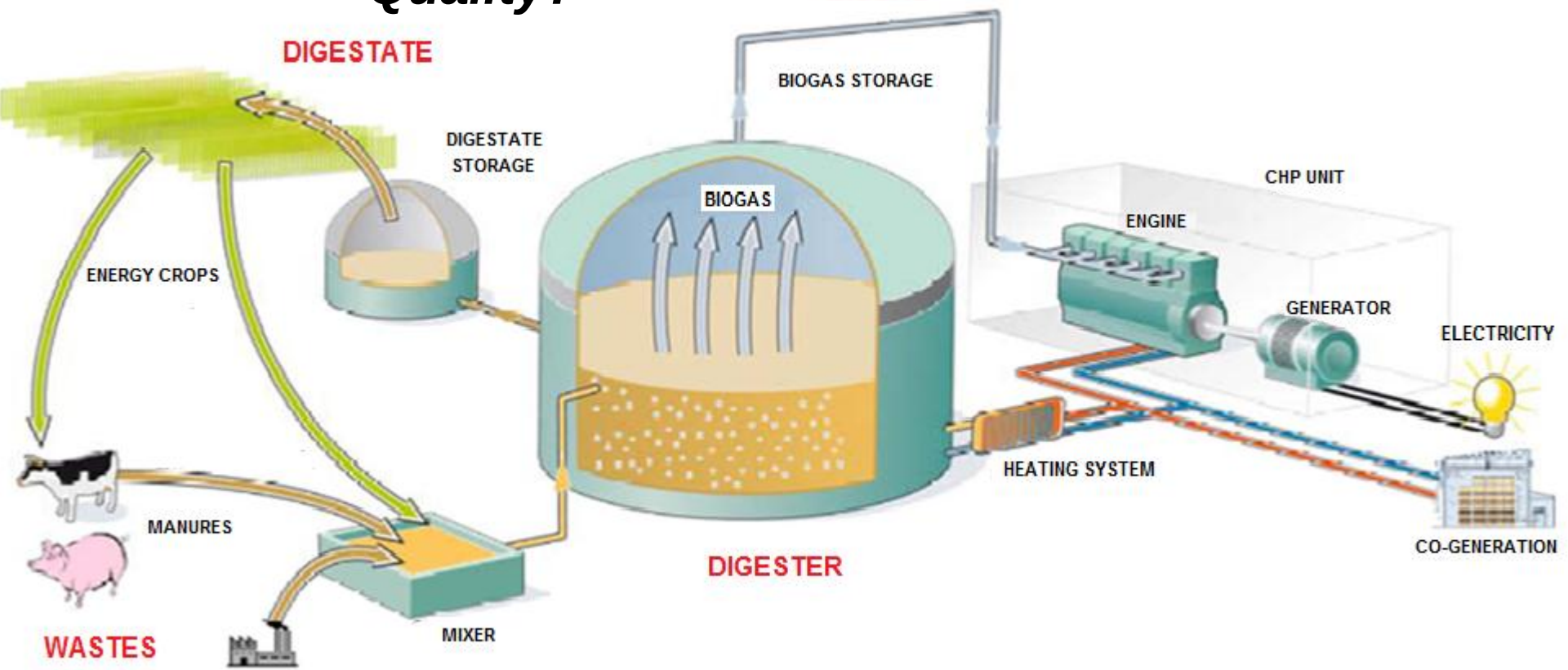
BIOGAS **DIGESTATE**



Products: Biogas + Digestate

Quality?

Maximum production?

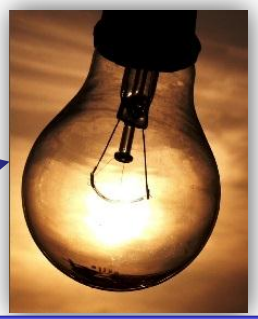


Proportions?

ANAEROBIC CO-DIGESTION

VARIOUS RESIDUES

ANAEROBIC CO-DIGESTION

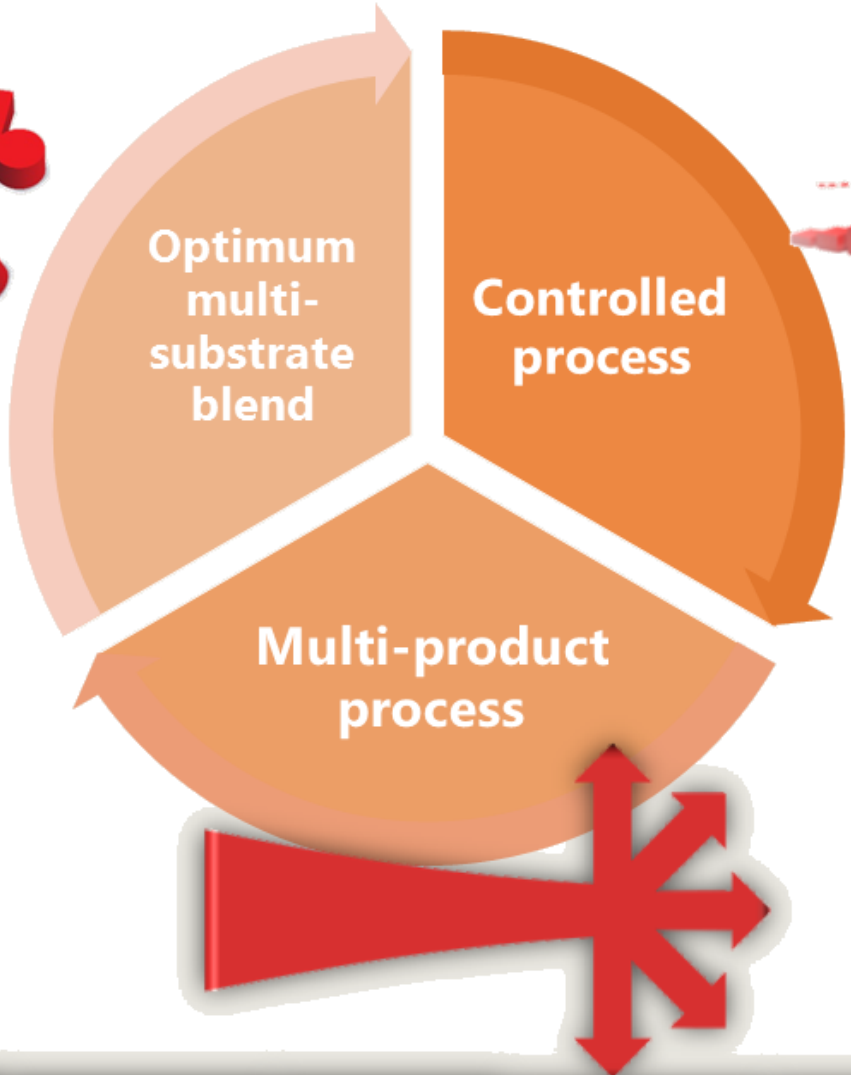


ELECTRICITY

SLUDGE

- ✓ **Manages** byproducts from diverse activities
- ✓ Produces renewable **energy constantly and predictibly**
- ✓ Produces **fertiliser**
- ✓ Prevents uncontrolled **methane emissions** (GHG)
- ✓ **Adds to local economies**

SOLUTIONS

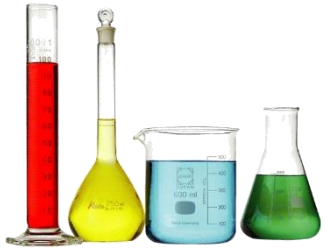

Optimum multi-substrate blend
Controlled process
Multi-product process

OPTIMUM SUBSTRATE BLEND

Low biogas production

Unstable process due to toxic components

Unadequate physicochmical characteristics



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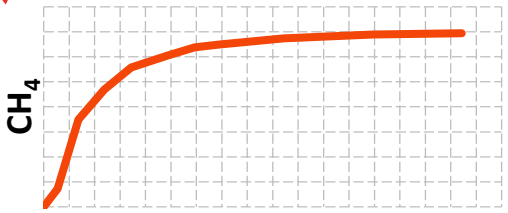


- **Larger biogas production**
- **More stable process**
- **Optimum operational conditions**

A MULTI-PRODUCT PROCESS



92.9%

6.8%

0.3%

70,000 ton/y

Pretreatment

37°C
12 h

Biogas upgrade and storage

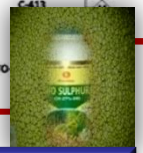
Biogas

411 m³/h

37°C
20 d

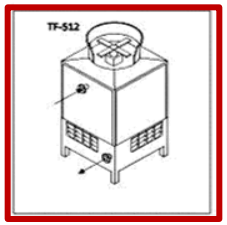
5,75 kg COD/m³ d

Anaerobic co-digestion



50 ton/y

70°C
30 min



Organic fertiliser production

12 weeks

12,000 ton/y

6,700 MWh/y

Energy co-generation

1.15 MW

7,800 MWh/y

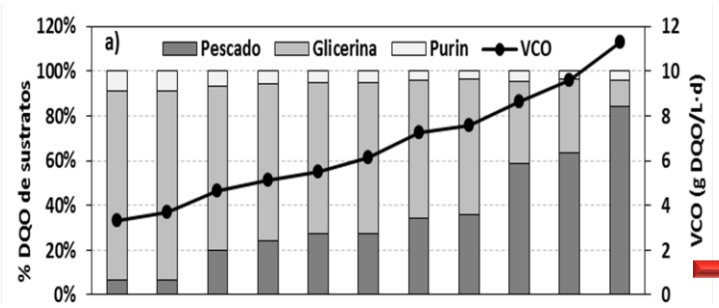
57,000 ton/y

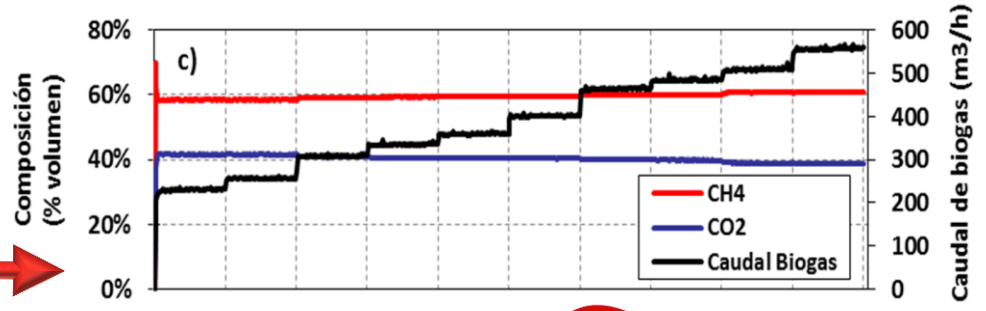
AcoD CONTROL CHALLENGES

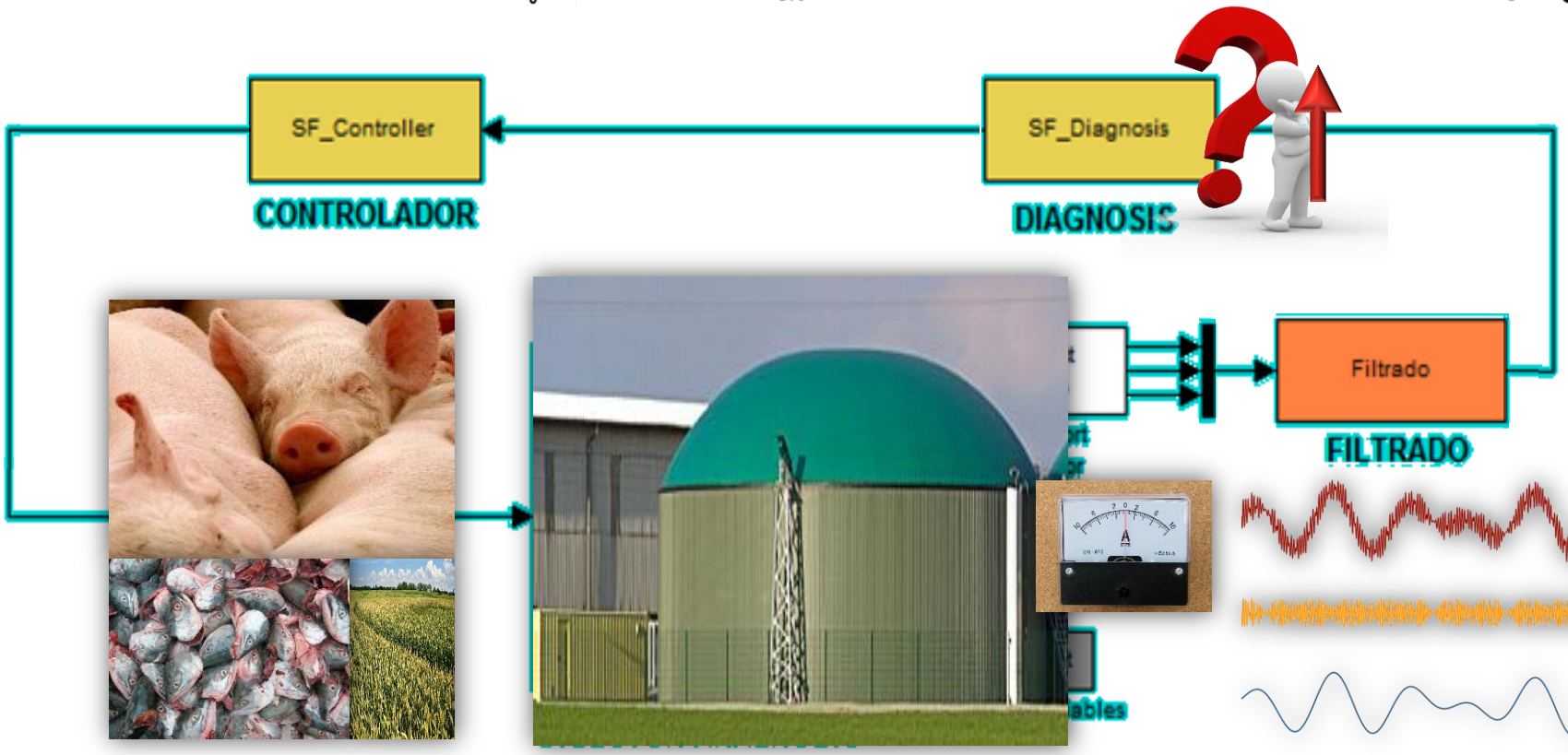
TO DEVELOP A CONTROL ESTRATEGY SUCH THAT:

- **Methane production and/or subtrate conversion are maximised.**
- **Can be directly implemented without extensive analytical data or modelling available, by making best use of standard information available in real plants.**
- **Process stability is maintained at all times.**
- **Continuous improvement is possible when better information about substrates or process becomes available.**
- **Information about the process limitations is obtained.**

CONTROLLED AND OPTIMISED PROCESS



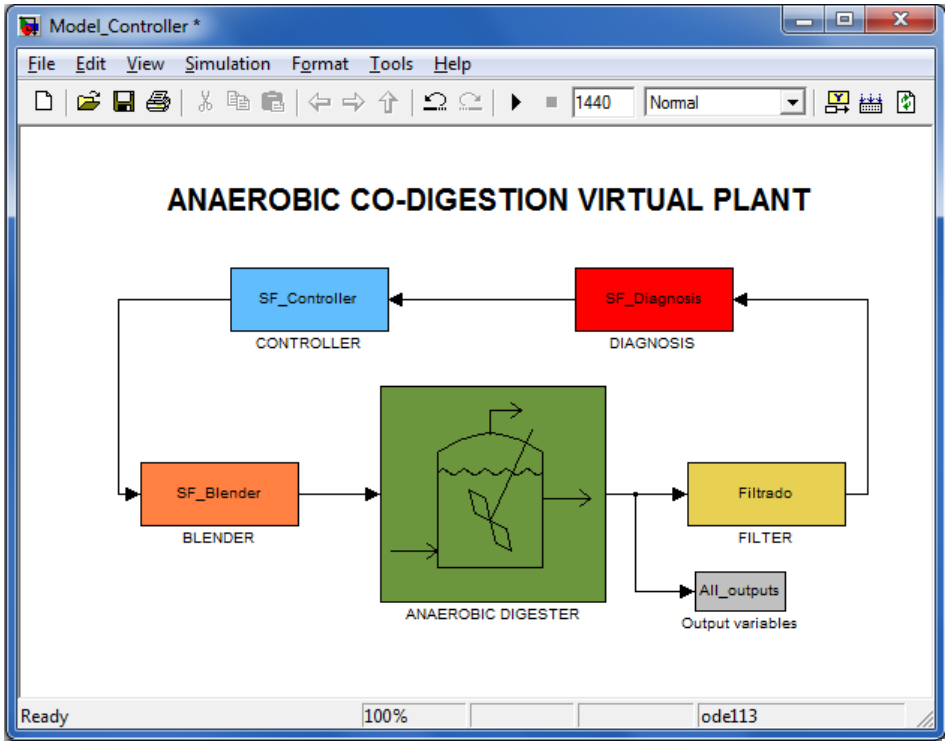




AcoD VURTUAL PLANT

Virtual Plant: ADM1-based AcoD model implemented in MATLAB/Simulink and validated at pilot scale.

Virtual Plant + Controller: built in MATLAB/Simulink and connected to the virtual plant



García-Gen, S., Lema, J.M., Rodríguez, J., 2013. Generalised modelling approach for anaerobic co-digestion of fermentable substrates. Bioresource Technology 147, 525–533.

SIMPLE SUBSTRATE CHARACTERISATION

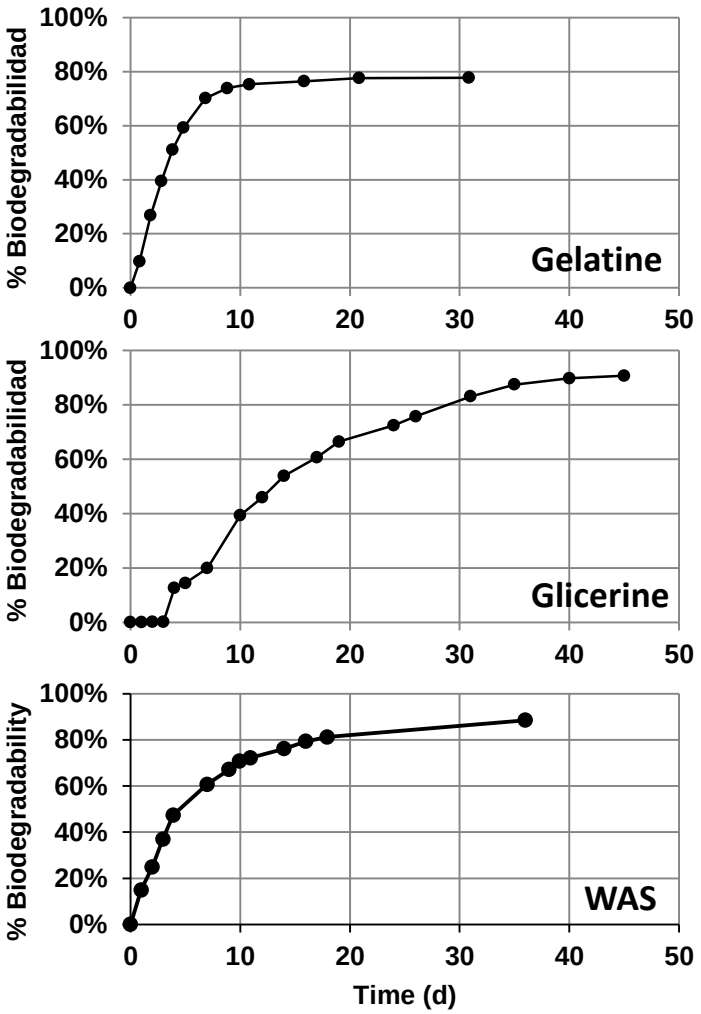
Substrates characterisation

Parameter	Gelatine	Glicerine	WAS
COD (gO2/L)	100.8	1478	30.79
TS (g TS/L)	0.0	756	28.30
VS (g VS/L)	0	693.3	20.80
TKN (gN/L)	12.88	0.00	1.44
NH4 (gN/L)	0.00	0.00	0.02
Total Alkalinity (gCaCO3/L)	1.8	38.4	2.2
Proteins (g/L)	80.5	0.06	8.90
Lipids (g/L)	0.00	0	4.09
Carbohydrates (g/L)	0.00	651	7.81
Liquid fraction (g liq/wet kg)	1000	199	972
Density (wet kg/L)	1.037	0.944	1.000
% Biodegradability	77.75	90.64	88.46

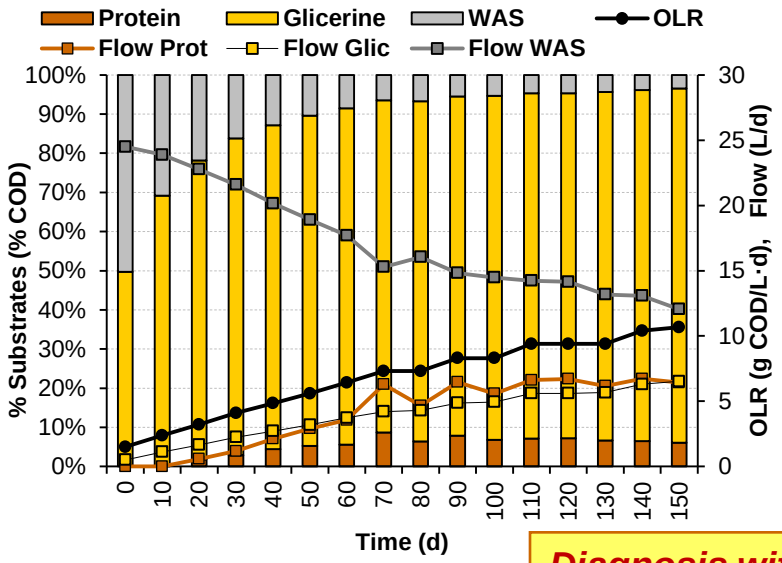
Operating conditions

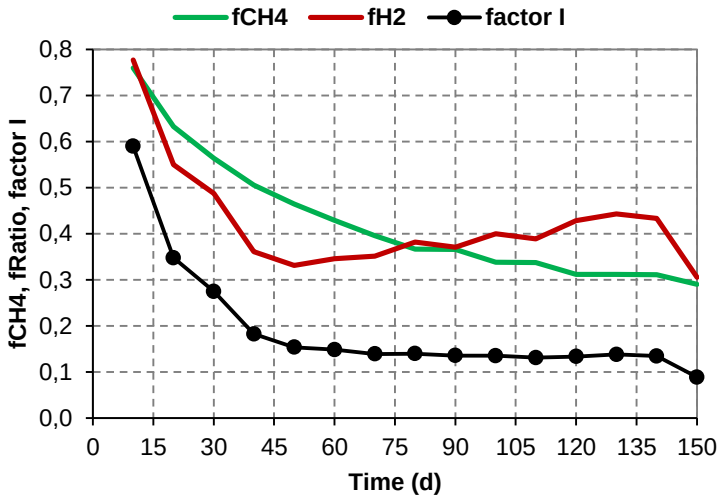
$V_{REACTOR}$ = 1.2 m^3 ; $[Biomass]_0$= 13 g VSS/L ; T = 37 °C

BMP tests

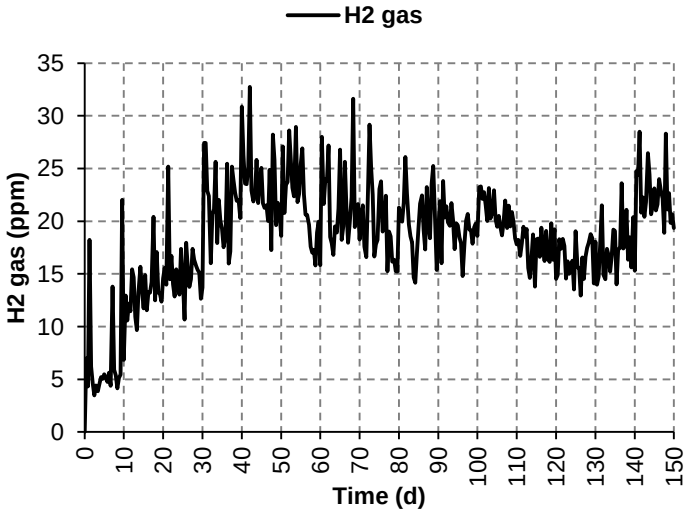


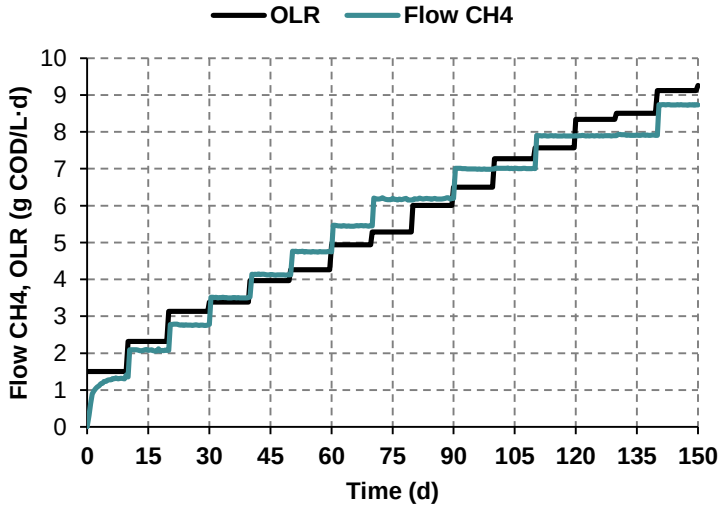
RESULTS: VIRTUAL PLANT + CONTROL SYSTEM





Diagnosis with Hidrogen gas





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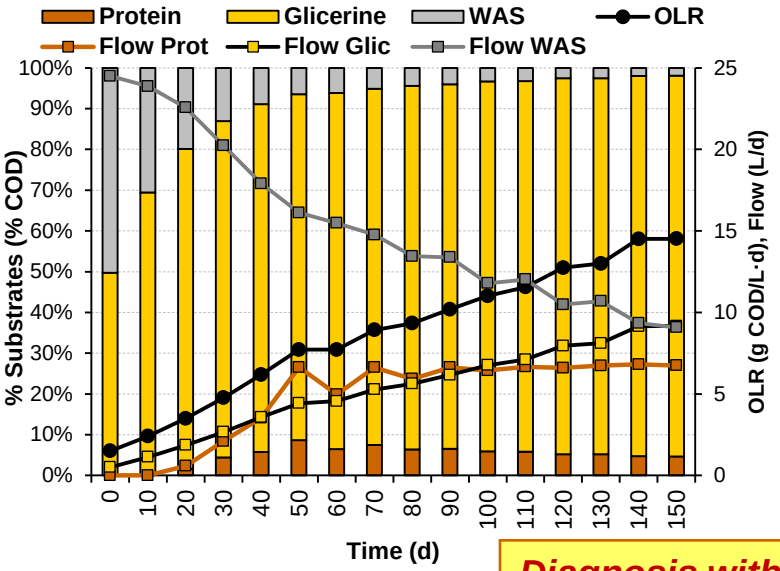
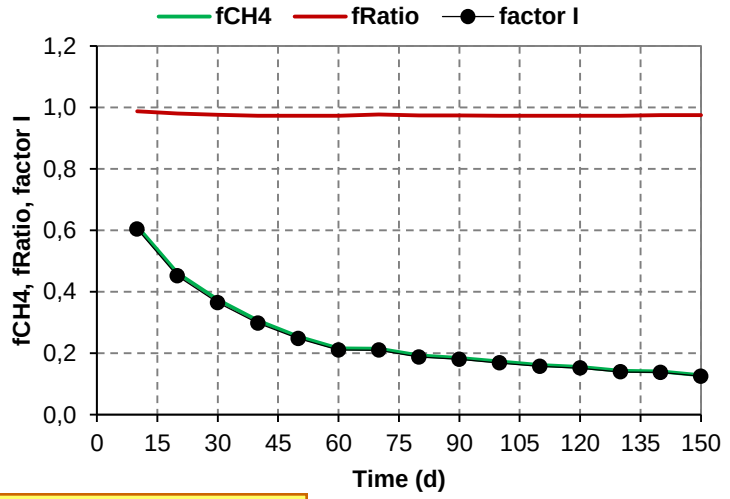
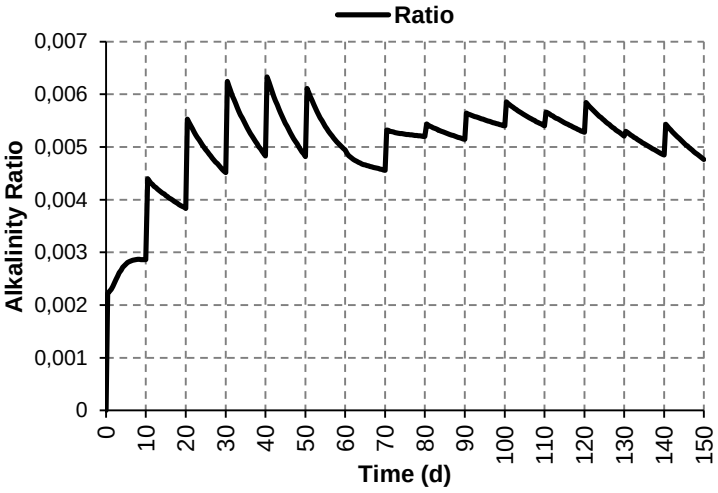
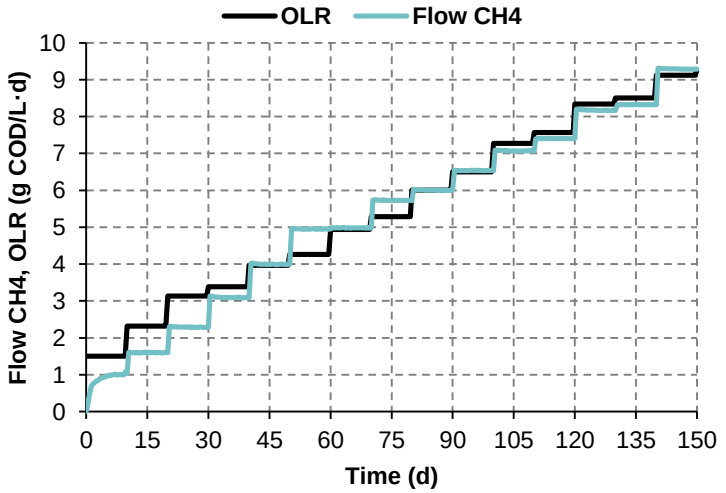
RESULTS: VIRTUAL PLANT + CONTROL SYSTEM



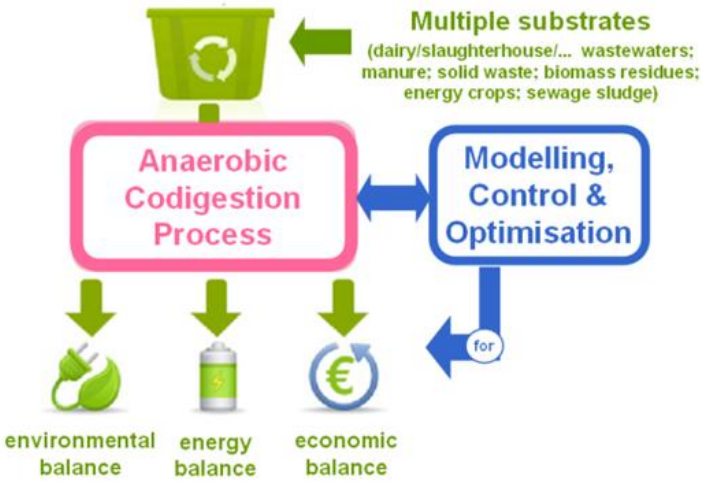


Diagnosis with Alkalinity Ratio





TAKE-HOME



Good models and characterisation of substrates allow for the prediction of **anaerobic co-digestion** processes performance.

Conventional simple analysis (such as COD and BMP) are sufficeint to **define optimum blends** of substrates and the **HRT of the system**.

Research efforts are in progress **at the USC (Spain) and Masdar Institute (UAE)** towards the development of **model based tools** allowing for accurate dynamic process simulation, optimisation and substrate blending **as well as economic impacts** on the plant revenue for dynamic pricing of sbstrates treatment.

QUESTIONS?

Jorge Rodríguez *PhD MSc FHEA* | د. خورخي رودريغاز
Assistant Professor
Department of Chemical & Environmental Engineering (CEE)
Masdar INSTITUTE معهد مصدر
PO Box 54224 Abu Dhabi
United Arab Emirates
D +971 2 810 9173
jrodriguez@masdar.ac.ae
www.masdar.ac.ae