

Anaerobic digestion of agricultural and agro-industrial wastes in Uruguay: development and technologies adaptation

MSc. Qco. Guillermo Zinola

Professor.

Department of Environmental Sustainability. Technological University of Uruguay (UTEC). Uruguay



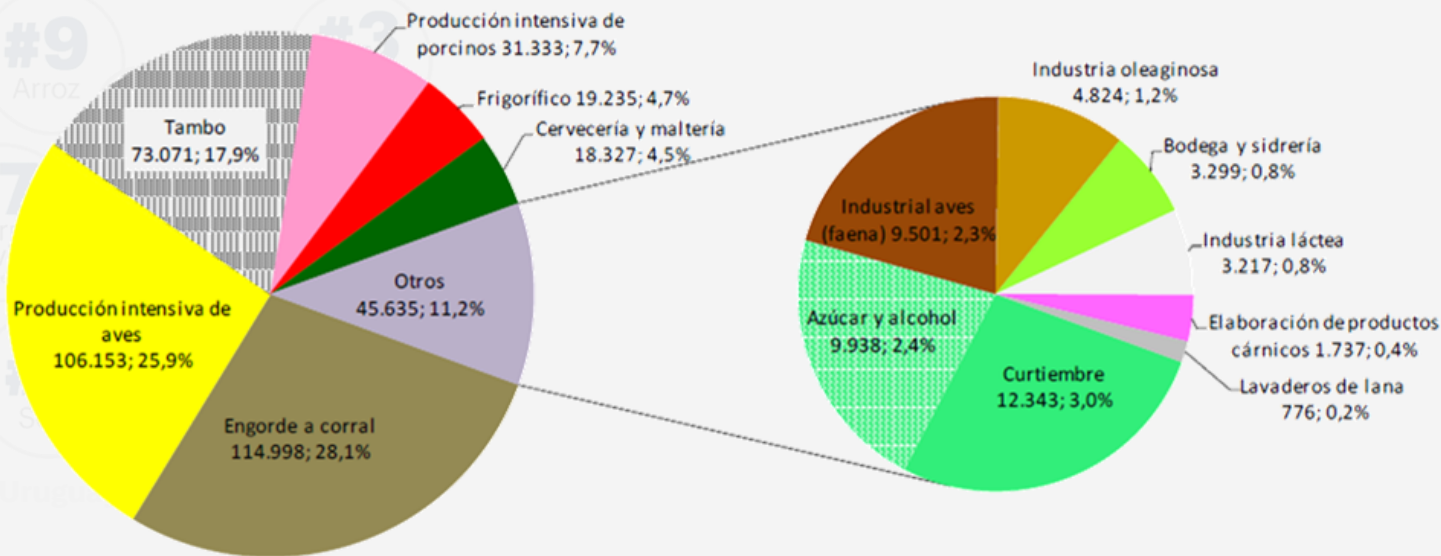
Uruguay as a
global supplier

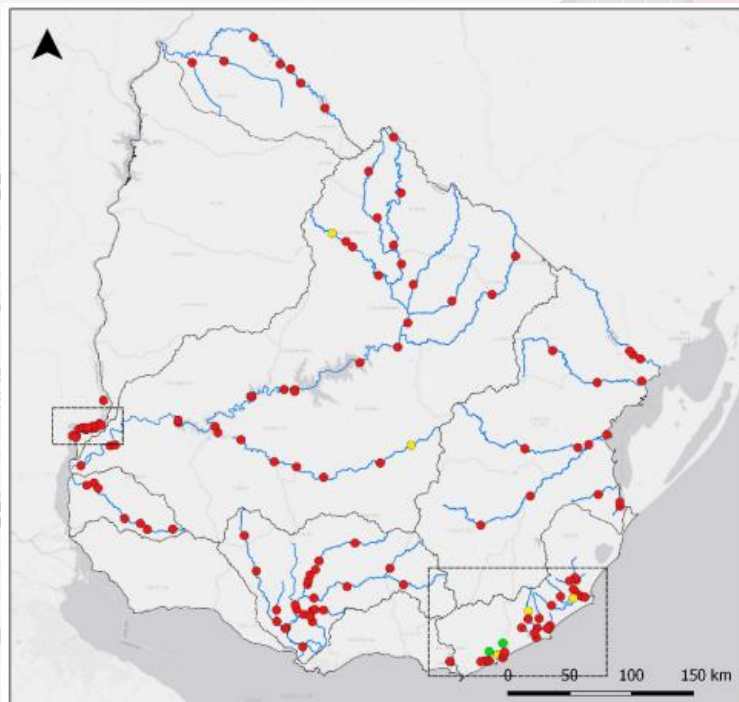
Agricultural and agroindustrial waste generation



PROYECTO
BIOVALOR

*Generando valor con
residuos agro-industriales*





Fósforo Total 2016-2019

Sistemas	Categorías	Fósforo Total (mg/L)
Lóticos	Buena	< 50
	Aceptable	51-70
Lénticos	Buena	< 30
	Aceptable	31-50

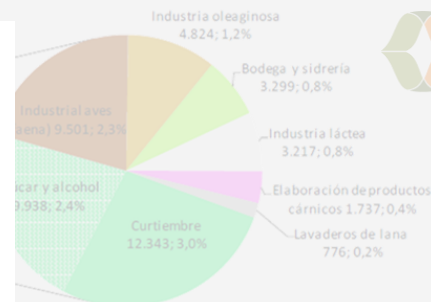
Río Uruguay



Lagunas Costeras



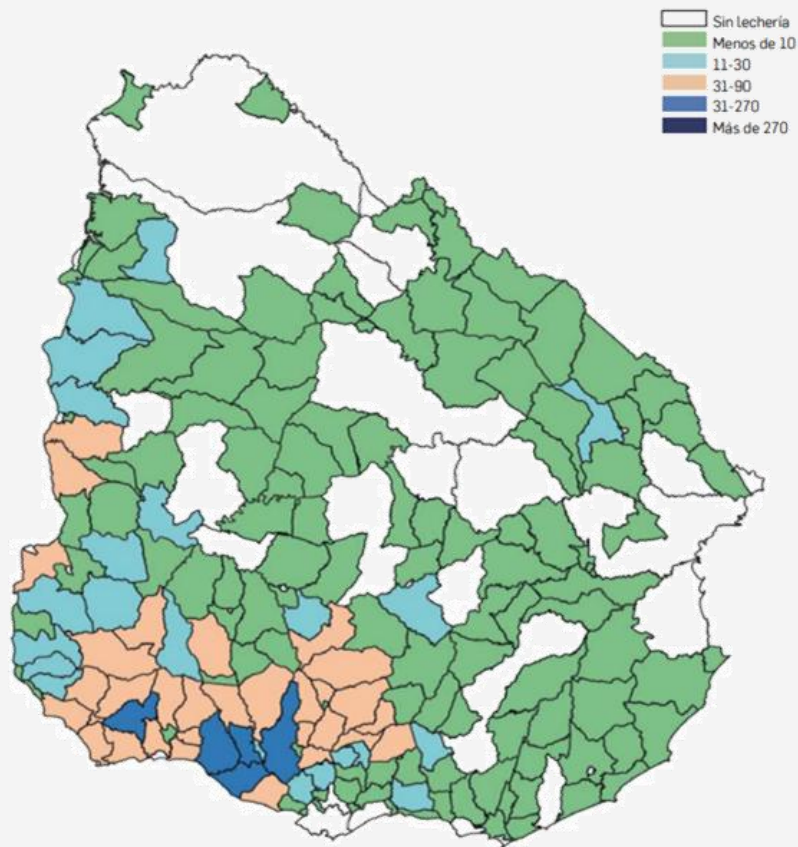
Título: Fósforo Total 2016-2019	Proyección: UTM 21S
Autor: Departamento de Evaluación Ambiental Integrada División Calidad Ambiental	Fecha: Noviembre 2020



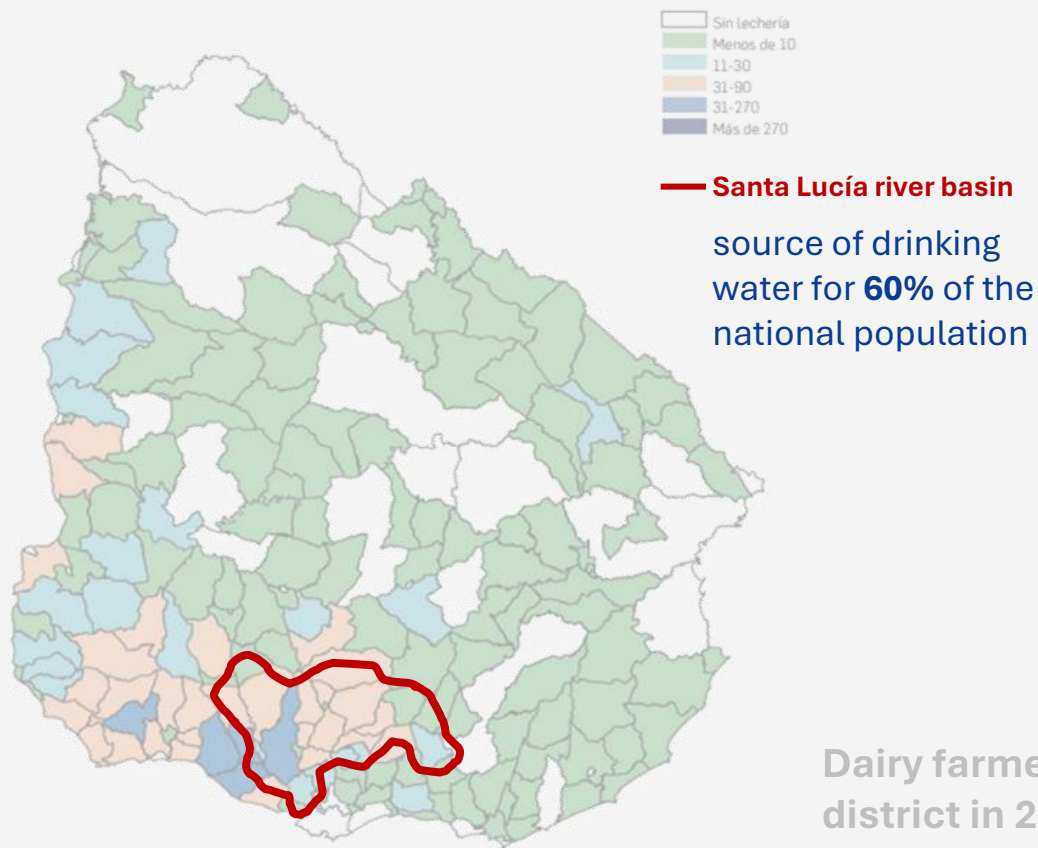
PROYECTO BIOVALOR
Generando valor con residuos agro-industriales

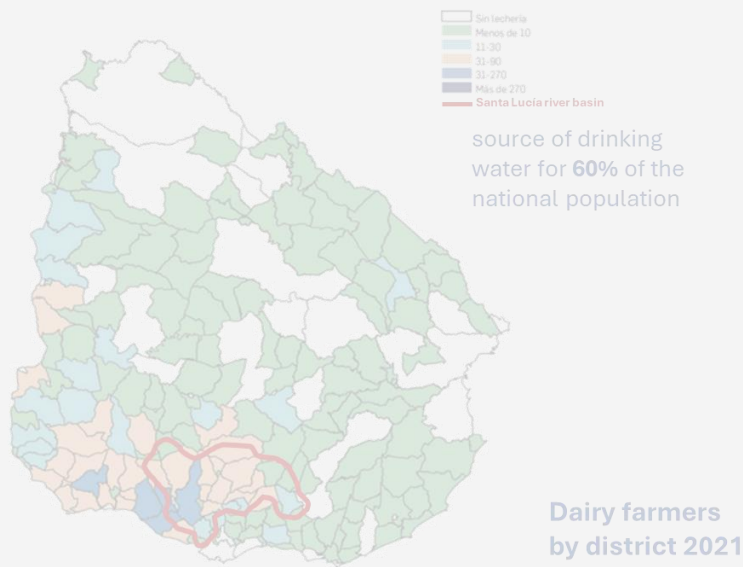
ur and agroindustrial wastes generation

**P concentration
in surface water**

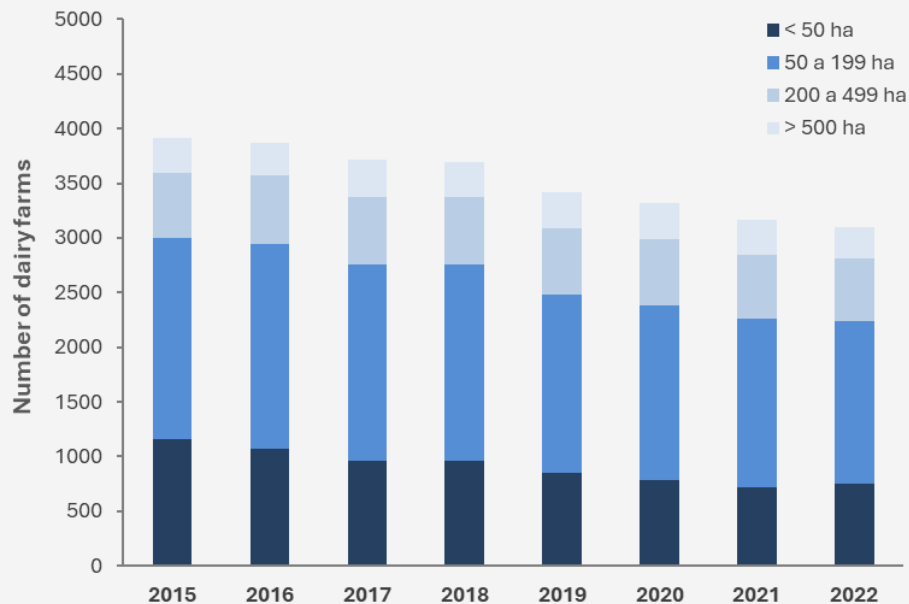


Dairy farmers by district in 2021





Dairy farms according to surface area



Small-scale farms are 70% of total

Environmental impact of dairy farms in Uruguay

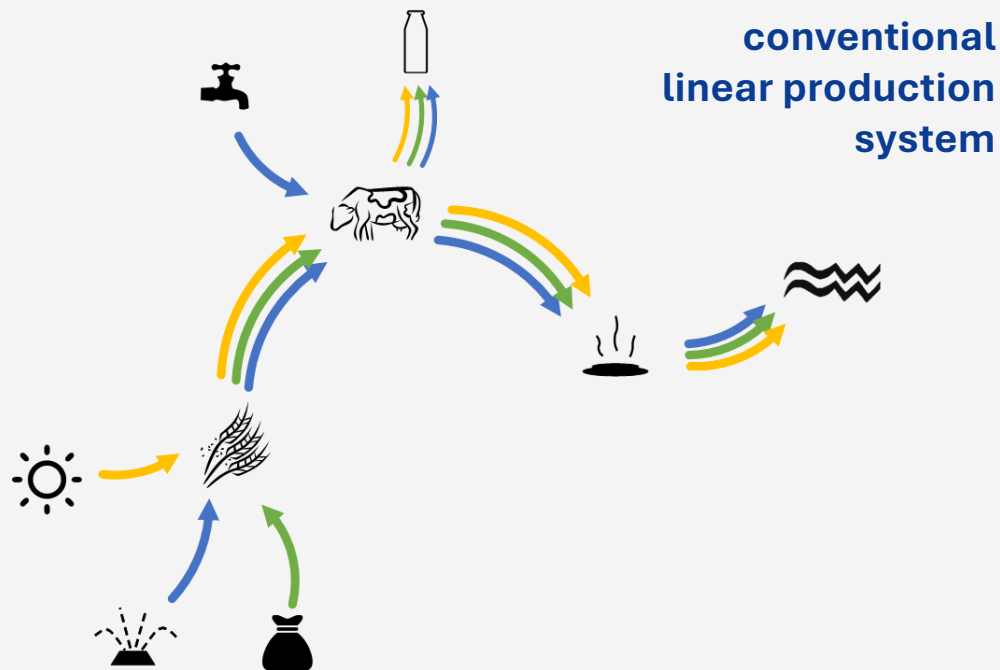
Indicador	Parámetro	Resultado	Unidad
Erosión	Pérdida de suelo	1,1 5x10 ⁶	ton/año
		1,53	ton/(ha.año)
Índice de P	Fósforo total	2001	ton /año
		0,003	Ton/(ha.año)
Exportación de nutrientes desde fuentes difusas	Nitrógeno total	N/D	ton/año
	Fósforo total	2.000	ton /año
Exportación de materia orgánica y nutrientes desde fuentes puntuales	Nitrógeno total	2486	ton/año
	Fósforo total	1038	ton /año
	Materia orgánica	10.400	ton /año
Residuos	Generación estiércol	327.017	ton MS/año
	Generación estiércol	213.022	ton MS/año
Consumo de agua ⁽²⁾	Agua alimento	8.520.872	m ³ /año
	Agua limpieza	5.757.346	m ³ /año
Consumo de energía	Energía fósil	178.334	tep/año
Plaguicidas en agua	Plaguicidas	3515	PAF m ³ / ciclo
Plaguicidas en suelo	Plaguicidas	1290	PAF m ³ / ciclo

ENVIRONMENTAL IMPACT OF DAIRY PRODUCTION IN URUGUAY

E1

Environmental impact of dairy farms in Uruguay

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Indian type digesters individual efforts (1990 - 2015)



Indian type digesters. a: Floating biogas-holder in Escuela Agraria de Durazno (2024). b: Elevated mixing tank in Escuela Agraria de Durazno (2024). c: Unoperated reactor in Colonia dairy farm (2019).

BIODIGESTERS IN SMALL-SCALE DAIRY FARMS: Experiences in Uruguay

E1

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Low-cost tubular digesters PPD/FMAM/PNUD (2008 - 2011)



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Indian type digesters individual efforts (1990 - 2015)



MANUAL FEEDING
CONCRETE BREAKAGE

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Low-cost tubular digesters PPD/FMAM/PNUD (2008 - 2011)



INTENSIVE MANUAL OPERATION
GREENHOUSE AND SLOPE STABILIZATION

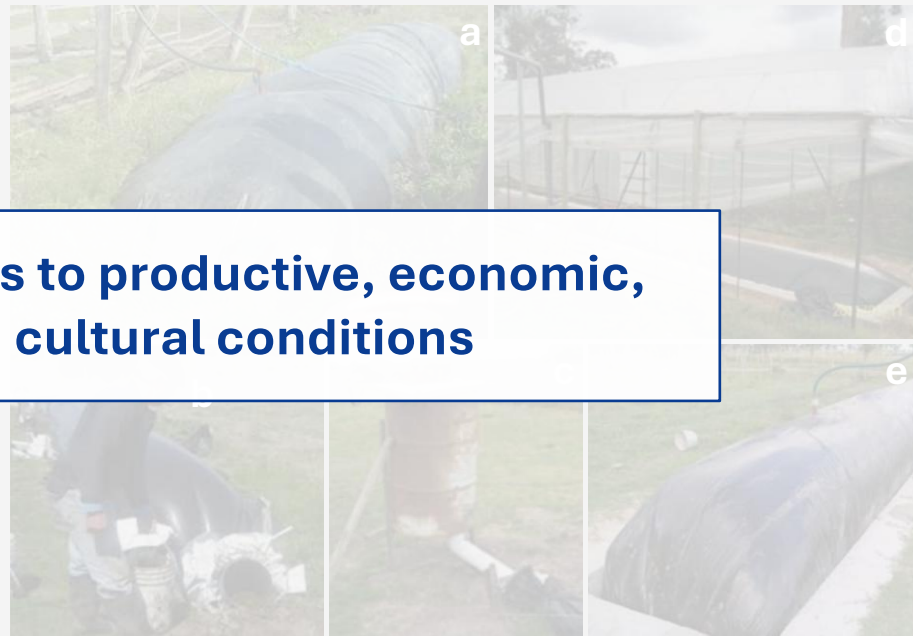
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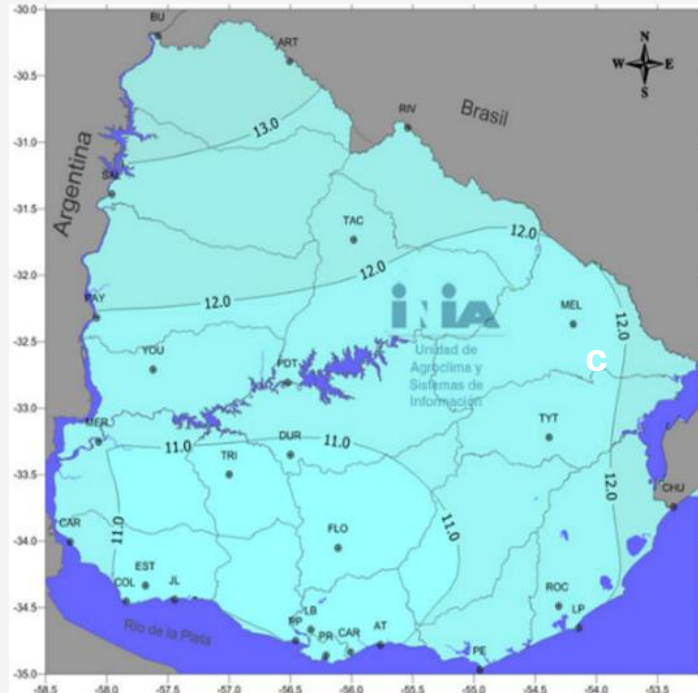
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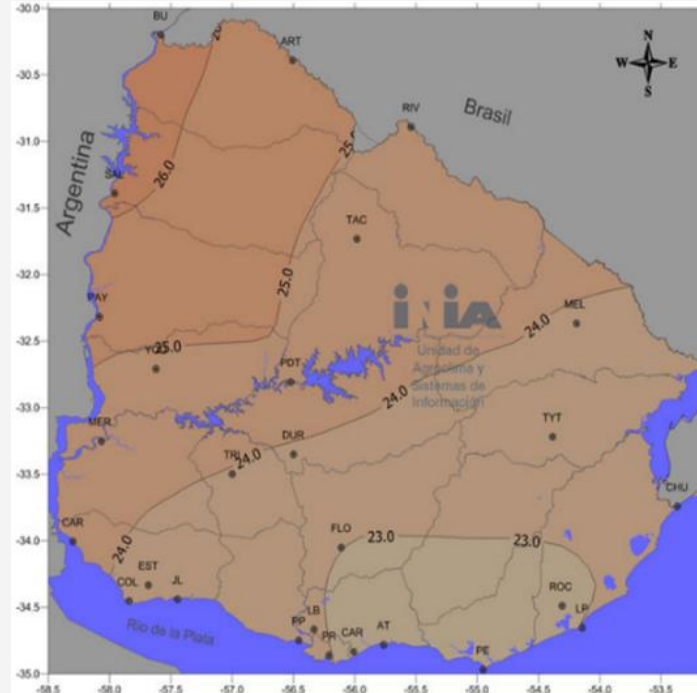
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**adaptation of technologies to productive, economic,
environmental and cultural conditions**

Seasonal temperature fluctuation

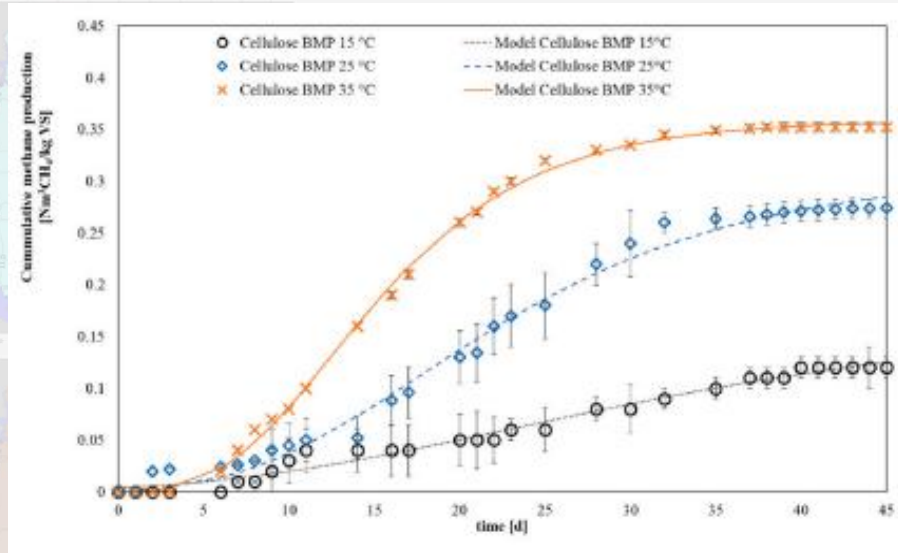


WINTER
July

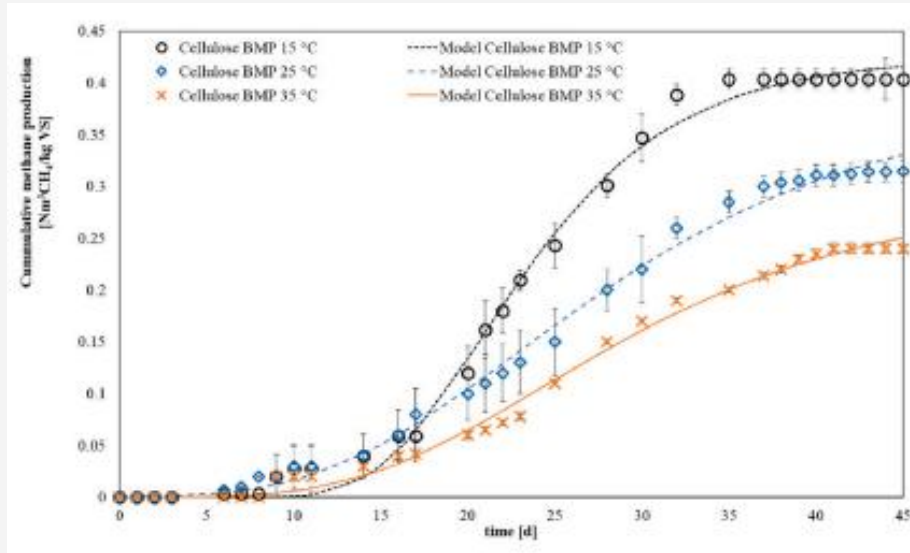


SUMMER
January

Seasonal temperature fluctuation

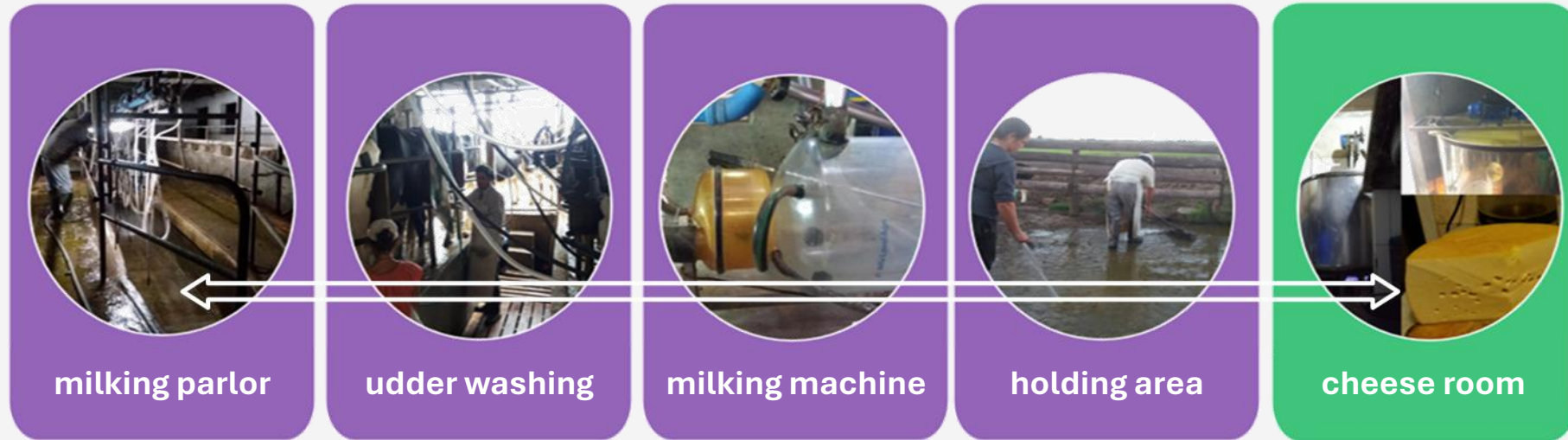


Inoculum acclimation
35°C



Inoculum acclimation
25°C

Differences in effluent production



Effluent estimation by water consumption in cleaning processes

Differences in effluent production



Water consumption in clean processes

Establecimiento			Operativa del ordeño			Consumo de agua en limpieza (L/Vo.d)	Manejo actual de efluentes	
			Vacas (Vo)	Organos (n)	Tiempo (h/d)		Limpieza	Gestión
Freddy Nieto	Quesería	Paso Panta	48 (70)	4 (6)	3.5 (2.0)	21.1 (25.3)	BS + LM	LA + D
Humberto Camacho	Quesería	Jesús María	64 (80)	7 (7)	2.0 (1.8)	35.6 (28.5)	LM	C + D
Johan Lecchini	Quesería	Manatiales	43 (50)	3 (6)	4.2 (3.5)	75.7 (37.9)	LM	LA + D
María Esther Foster	Quesería	Jesús María	14 (25)	2 (2)	2.2 (2.0)	47.4 (28.4)	BS + LB	C + D
Silvia Fernández	Quesería	Cerro	15 (30)	2 (6)	2.7 (2.0)	16.3 (24.5)	RP + LM	C + D
Raquel Delgado	Quesería	Jesús María	30 (50)	3 (3)	2.9 (2.6)	45.6 (31.9)	LM	LA + D
Ruben Delgado	Quesería	Manatiales	40 (60)	5 (5)	2.7 (2.5)	48.1 (30.1)	BS + LM	LAi
Fernando Benitez	Remitente	Paso del Rey	49 (70)	4 (8)	4.7 (3.0)	20.3 (30.5)	BS + LM	C + D
William Panzardi	Remitente	Juan Soler	43 (60)	5 (5)	4.0 (3.5)	40.0 (30.0)	BS + LB	C + D

Differences in effluent production



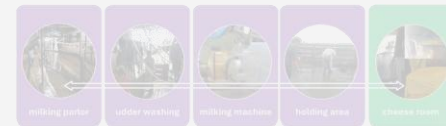
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50 L/VO.d

Reference value
used in Uruguay
(New Zealand)

Differences in effluent production



Water consumption in clean processes

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Reference value used in Uruguay (New Zealand)

Effluents production in small-scale farms depends on family traditions, production processes, water availability and environmental responsibility of each family



BIODIGESTERS ADAPTED TO THE CLIMATIC AND PRODUCTIVE CONDITIONS OF URUGUAY



BIODIGESTERS FOR SMALL-SCALE DAIRY FARMERS

Multi-predial project: Sustainable dairy in the Santa Lucía river basin

440 cows in 9 family farms and artisanal cheese factories in San José, Uruguay



96,4 kg/d

N-P-K+micro
(12-8-5)



25 kg/d

LPG



20 m³/d

undischarged
raw wastewater



Control

of pest and
odor



536 tCO₂eq

annually
unreleased GHG

BIODIGESTERS FOR SMALL-SCALE DAIRY FARMERS

Multi-predial project: Sustainable dairy in the Santa Lucía river basin

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NETUM



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GEI

536 tCO₂eq

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PARTNERS



BANCO MUNDIAL
BIRF • AIF | GRUPO BANCO MUNDIAL



MINISTERIO DE GANADERÍA
AGRICULTURA Y PESCA
REPÚBLICA ORIENTAL DEL URUGUAY
DIRECCIÓN GENERAL DE
DESARROLLO RURAL

DGDR
DIRECCIÓN GENERAL DE
DESARROLLO RURAL

Juntos,
para un desarrollo
con todos y para todos



San José
GOBIERNO DEPARTAMENTAL



SISTEMA.bio
CREATING VALUE FROM WASTE

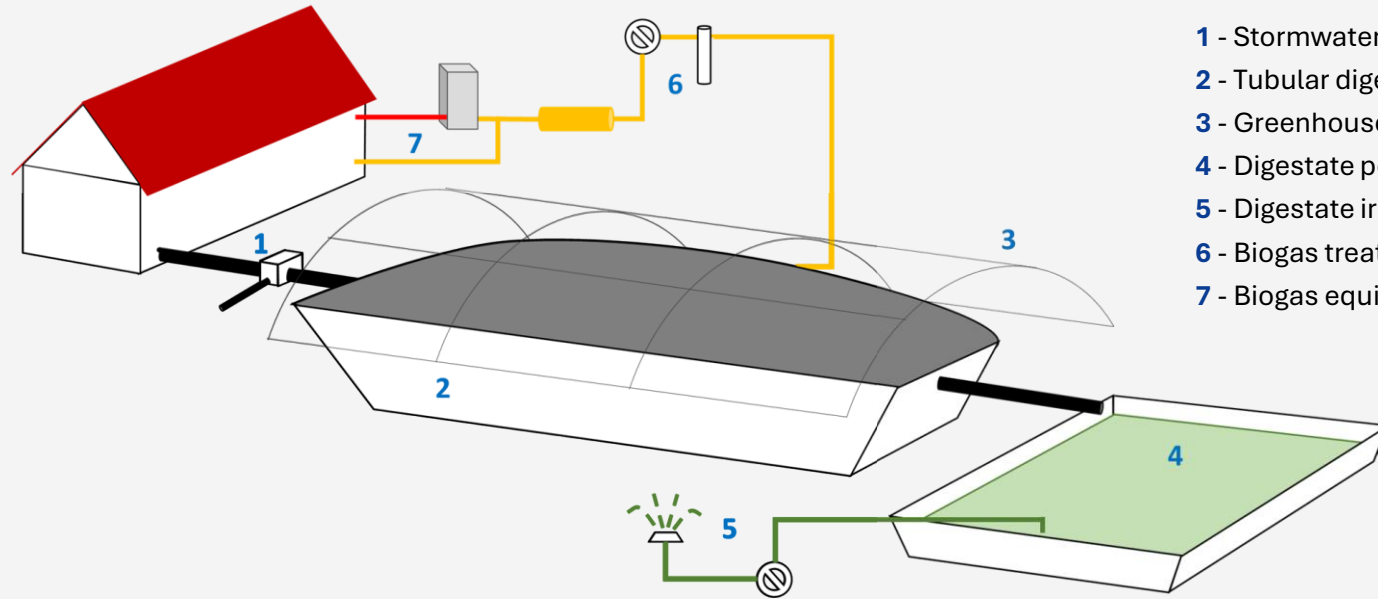


UTEC

Universidad Tecnológica

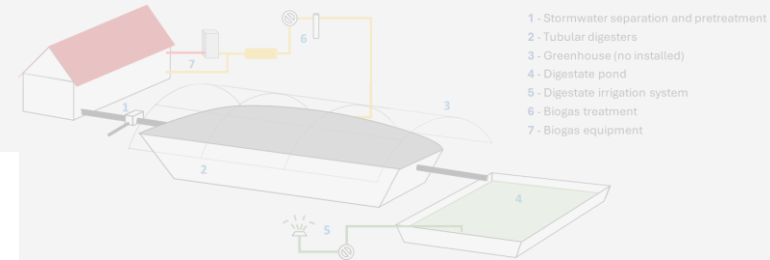


Improving technology design: Adaptation measures



- 1 - Stormwater separation and pretreatment
- 2 - Tubular digesters
- 3 - Greenhouse (no installed)
- 4 - Digestate pond
- 5 - Digestate irrigation system
- 6 - Biogas treatment
- 7 - Biogas equipment

Improving technology design: Adaptation measures

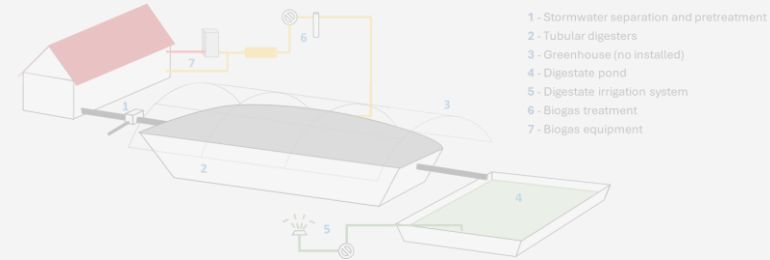


Feeding adapted to existing cleaning processes

Improving technology design: Adaptation measures



Feeding and
cleaning

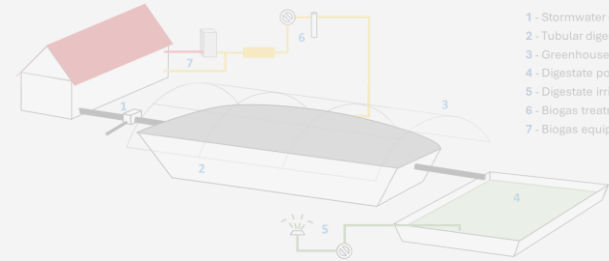


**Use of more resistant
materials in the digester
construction**

Improving technology design: Adaptation measures



Thermal insulation of the soil with high-density expanded polystyrene



- 1 - Stormwater separation and pretreatment
- 2 - Tubular digesters
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digester construction

BIODIGESTERS IN SMALL-SCALE DAIRY FARMS: Technology evaluation

E1

Case study: Ñieto family



Case study: Ñieto family



Artisanal cheese dairy

- 60 milking cows
- 6 milking units
- Average milking time: 1,26 h/cow.d
- Cleaning: Dry sweeping + washing with high-pressure hose
- Washing water consumption: 40 L/cow.d

Case study: Ñieto family



Artisanal cheese dairy

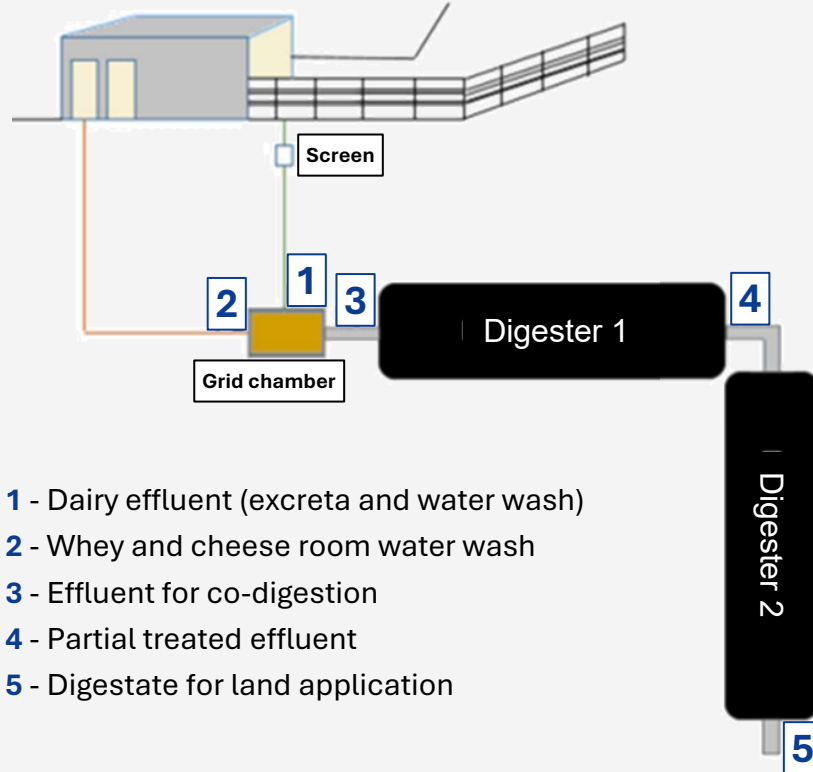
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Digesters

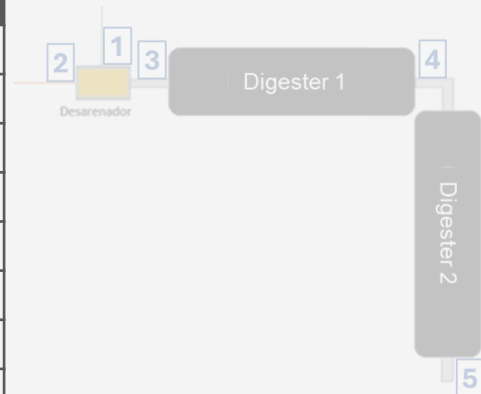
- Co-digestion of dairy effluent (excreta and wash water) and whey
- 2 biodigesters in series of 26 m³ each
- Q: 2.5 m³/d (1.5 m³/d)
- HRT: 21 d (35 d)
- OLR: 0.48 kgVS/m³.d

Effluents and digestate characterization

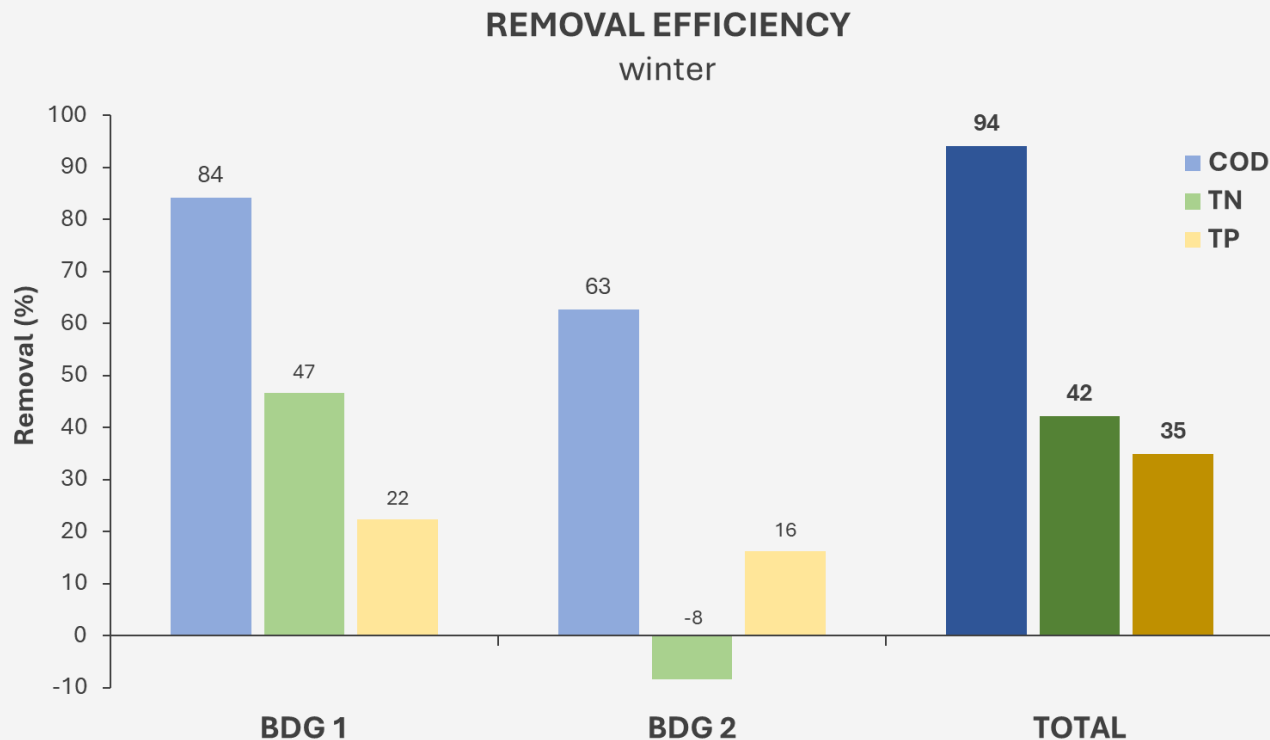


Effluents and digestate characterization

Parameters	Symbol	1	2	3	4	5	Unit
Flow	Q	2,24	0,24	2,49	2,49	2,49	m ³ /d
Hydrogen potential	pH	7,01	5,70	6,72	6,86	6,81	-
Conductivity	EC	3,63	3,99	3,66	4,54	4,89	mS/cm
Redox potential	REDOX	-0,17	97,10	0,27	-11,57	-6,90	mV
Total alkalinity	ALK	1.673	-	615	2.040	2.211	mgCaCO ₃ /L
Total solids	TS	20,75	36,76	19,31	4,92	3,12	gTS/L
Volatile solids	VS	9,44	33,72	10,12	2,11	1,06	gVS/L
Total suspended solids	TSS	19,08	5,21	14,63	2,86	0,44	gTSS/L
Volatile suspended solids	VSS	8,76	5,19	7,18	1,48	0,29	gVSS/L
Chemical oxygen demand	COD	12,80	44,00	16,20	2,55	0,95	gO ₂ /L
Total nitrogen	TN	440	510	450	240	260	mgN/L
Ammonium	NH ₄ ⁺	160	13	120	210	240	mgN-NH ₄ ⁺ /L
Total phosphorous	TP	184	173	183	142	119	mgP/L
Phosphate	PO ₄ ³⁻	81	8	103	123	111	mgP-PO ₄ ³⁻ /L

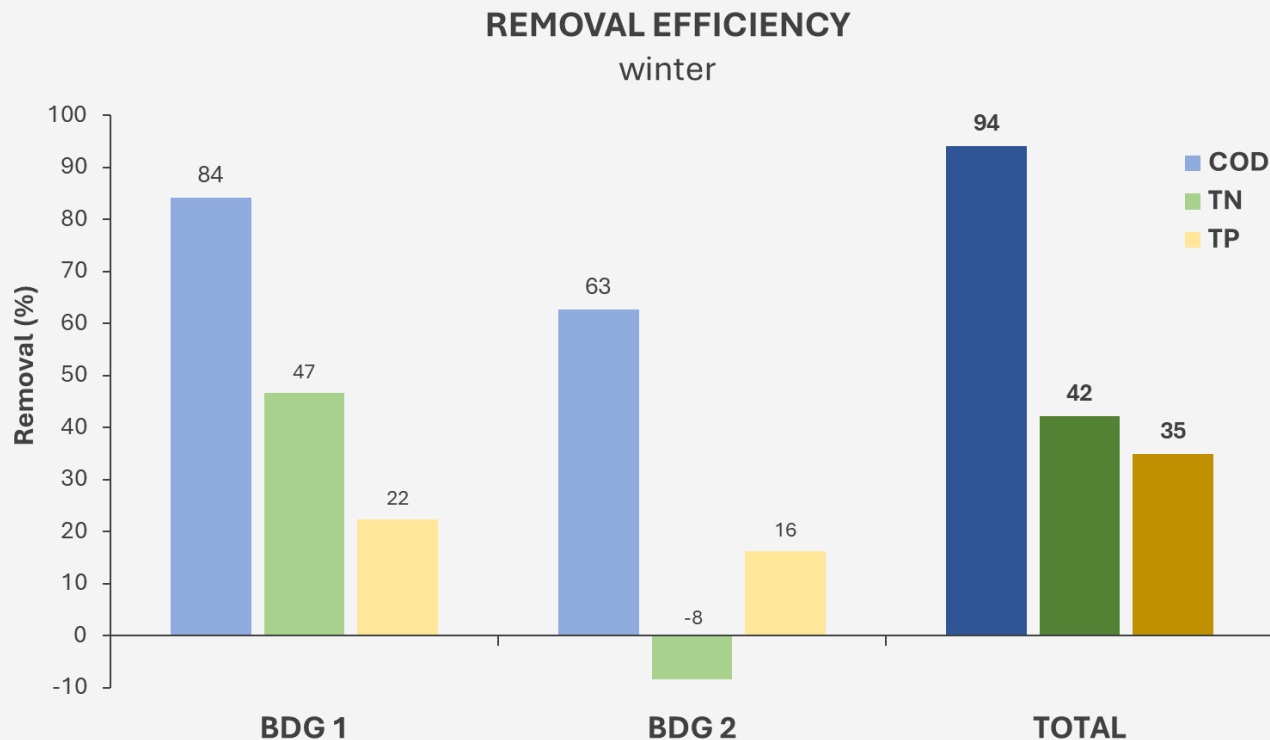


Removal efficiency



- High COD removal in winter (10 - 15 °C)

Removal efficiency



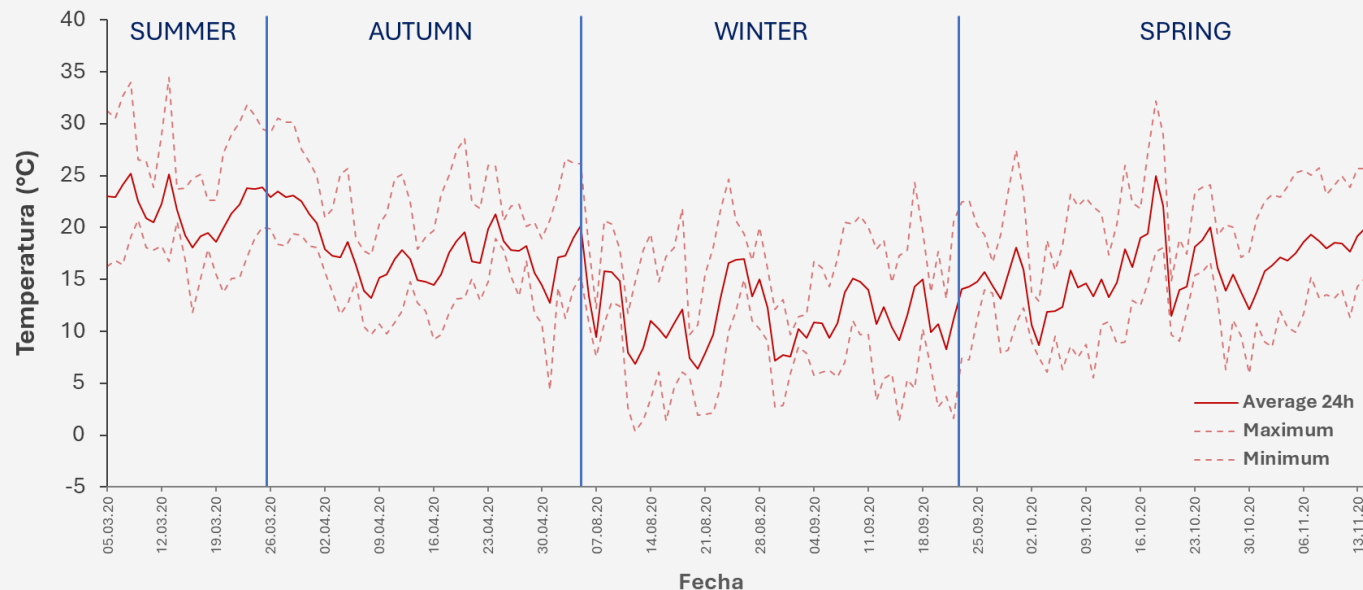
- High COD removal in winter (10 - 15 °C)

- **NT and PT removal indicate that solids may be accumulating in BDG 1**

Temperature behavior

AIR TEMPERATURE FLUCTUATION

daily average



Average temperature:

- Winter = 6 a 17°C
- Summer = 22 a 25°C

Temperature behavior



**Co-digestion under
psicrofilic process**

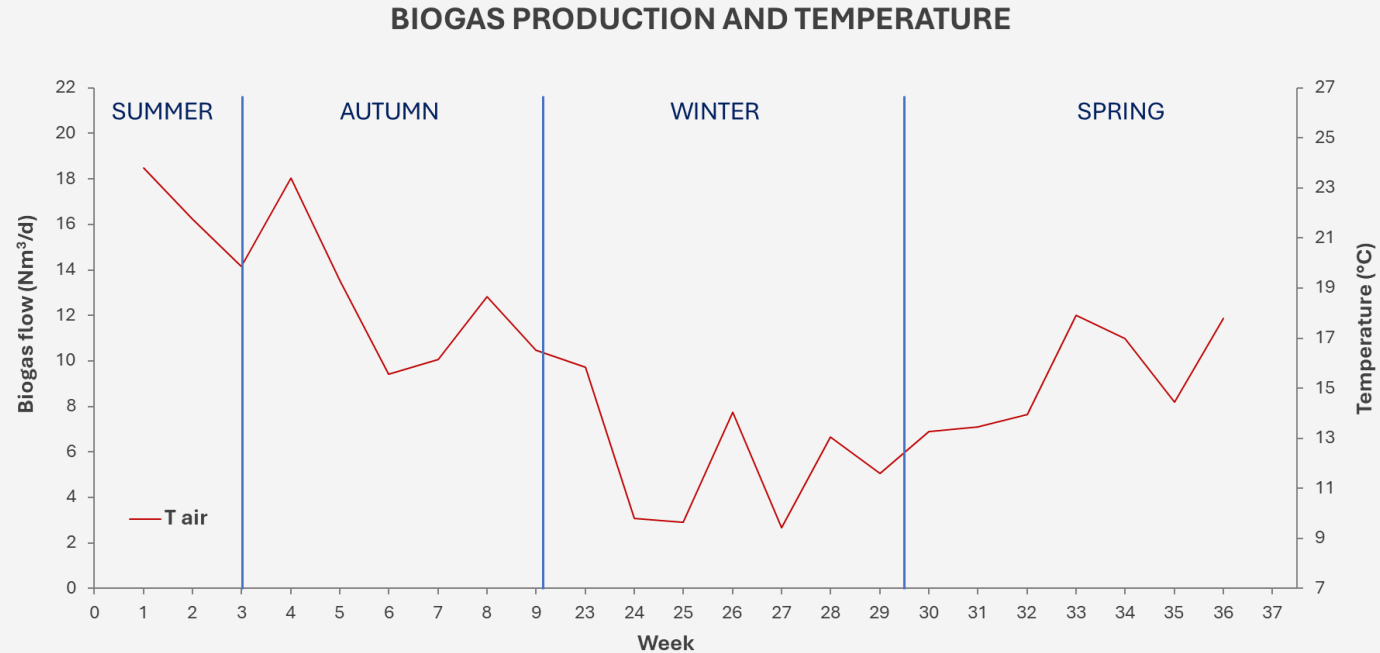
**Average
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- Winter = 6 a 17°C
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Biogas production

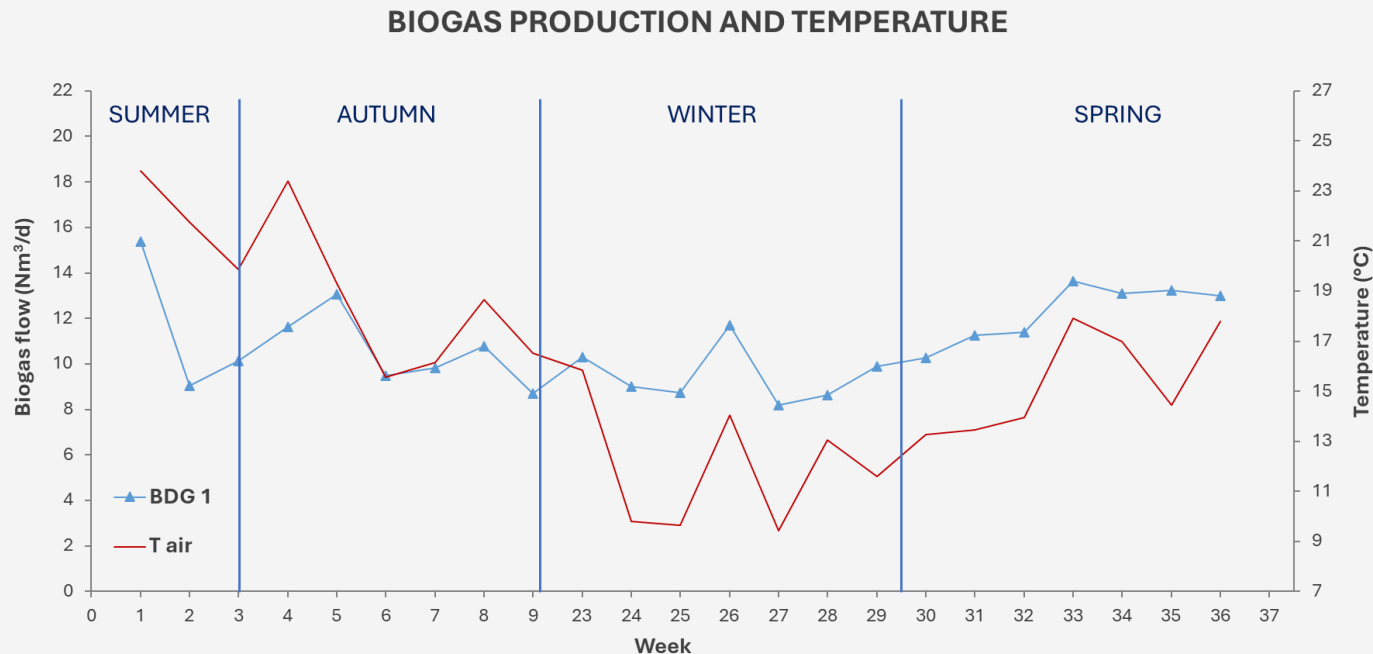
Biogas production
was related with T:



Biogas production

Biogas production
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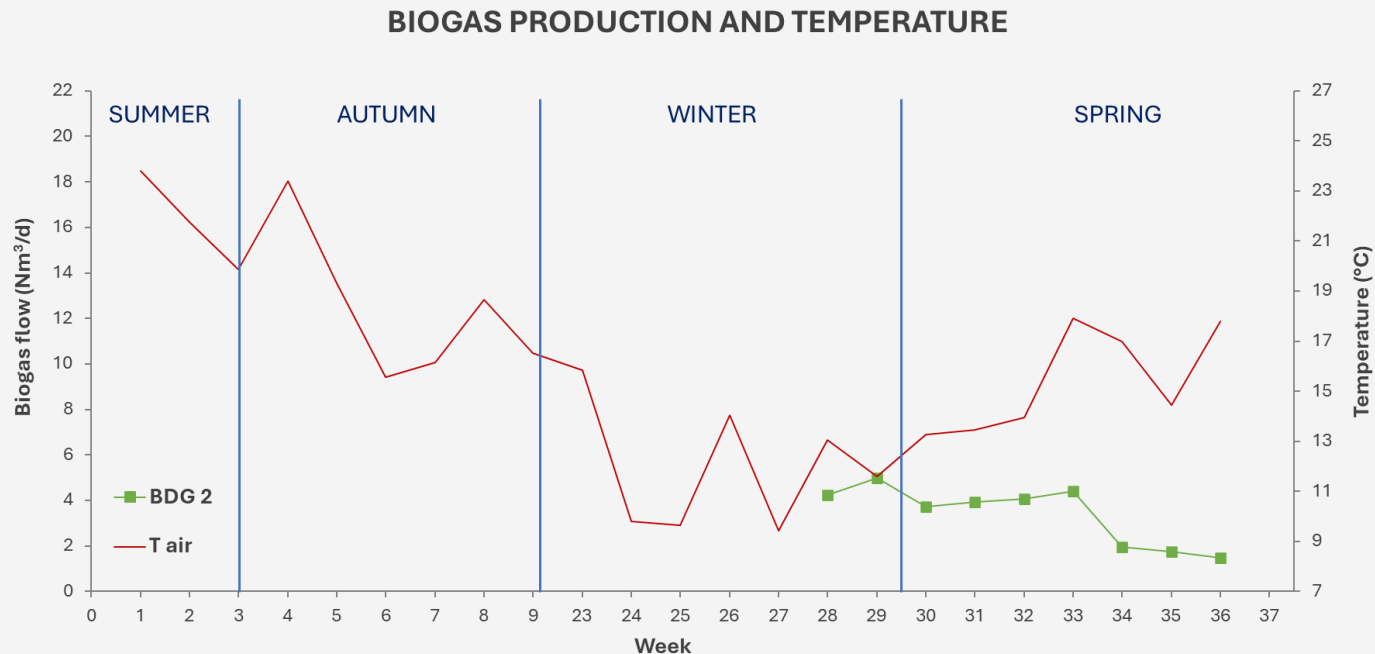
- BDG 1 $\uparrow$ when T $\uparrow$



Biogas production

Biogas production was related with T:

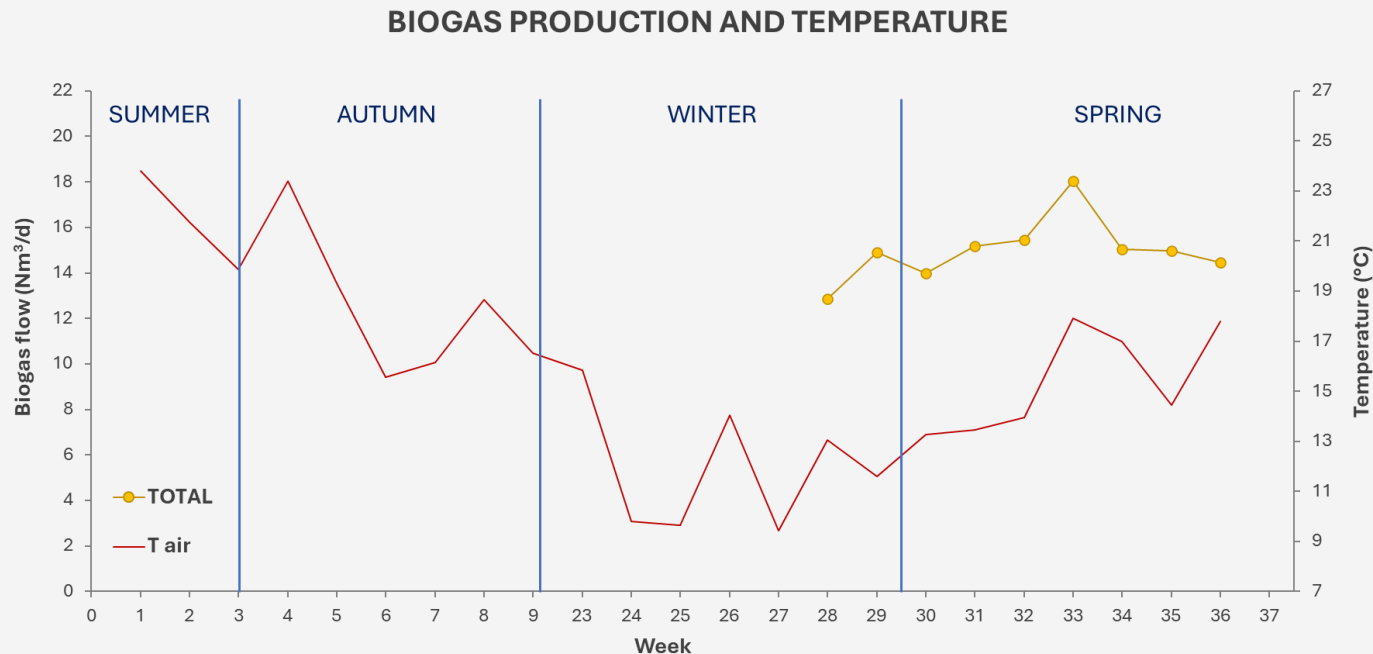
- BDG 1 $\uparrow$ when T $\uparrow$
- BDG 2 $\downarrow$ when T $\uparrow$



Biogas production

Biogas production
was related with T:

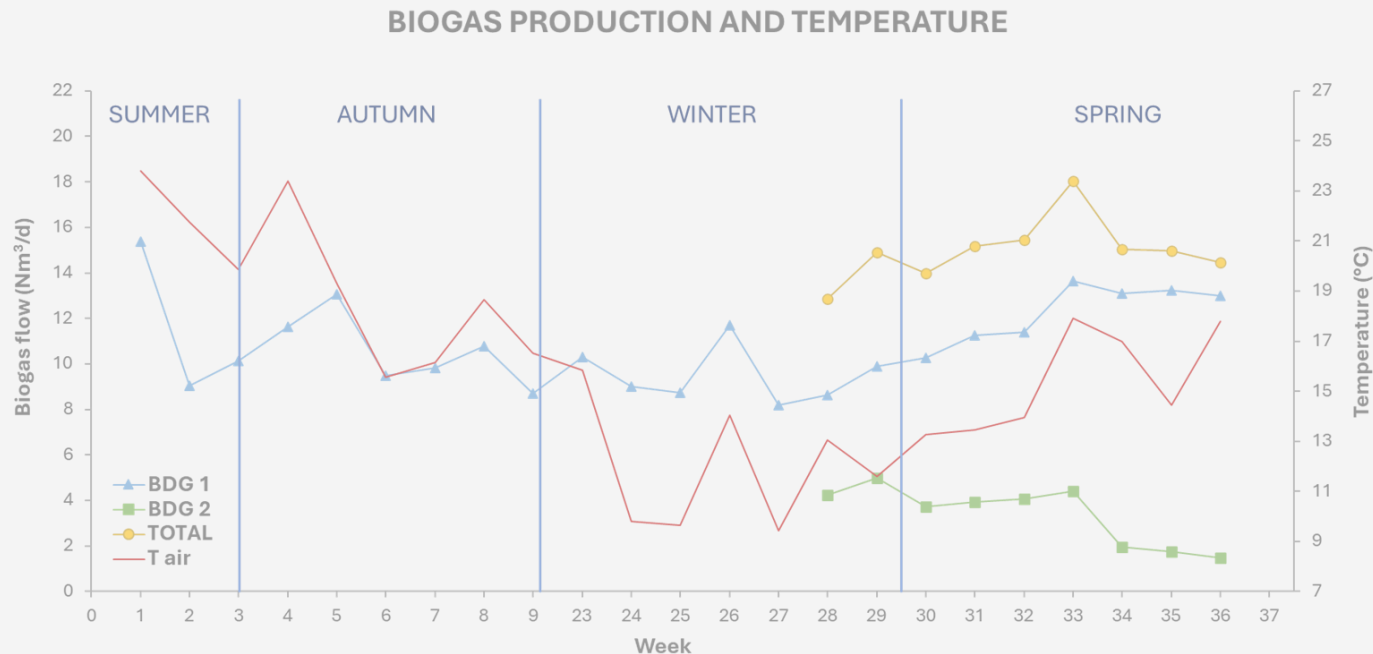
- BDG 1 $\uparrow$ when T $\uparrow$
- BDG 2 $\downarrow$ when T $\uparrow$
- **Total = when T $\uparrow$**



Biogas production

Biogas production was related with T:

- BDG 1 ↑ when T ↑
- BDG 2 ↓ when T ↑
- Total = when T ↑



Specific biogas productivity = $0,25 \pm 0,2 \text{ Nm}^3/\text{m}^3.\text{d}$

Biogas utilization



large burner



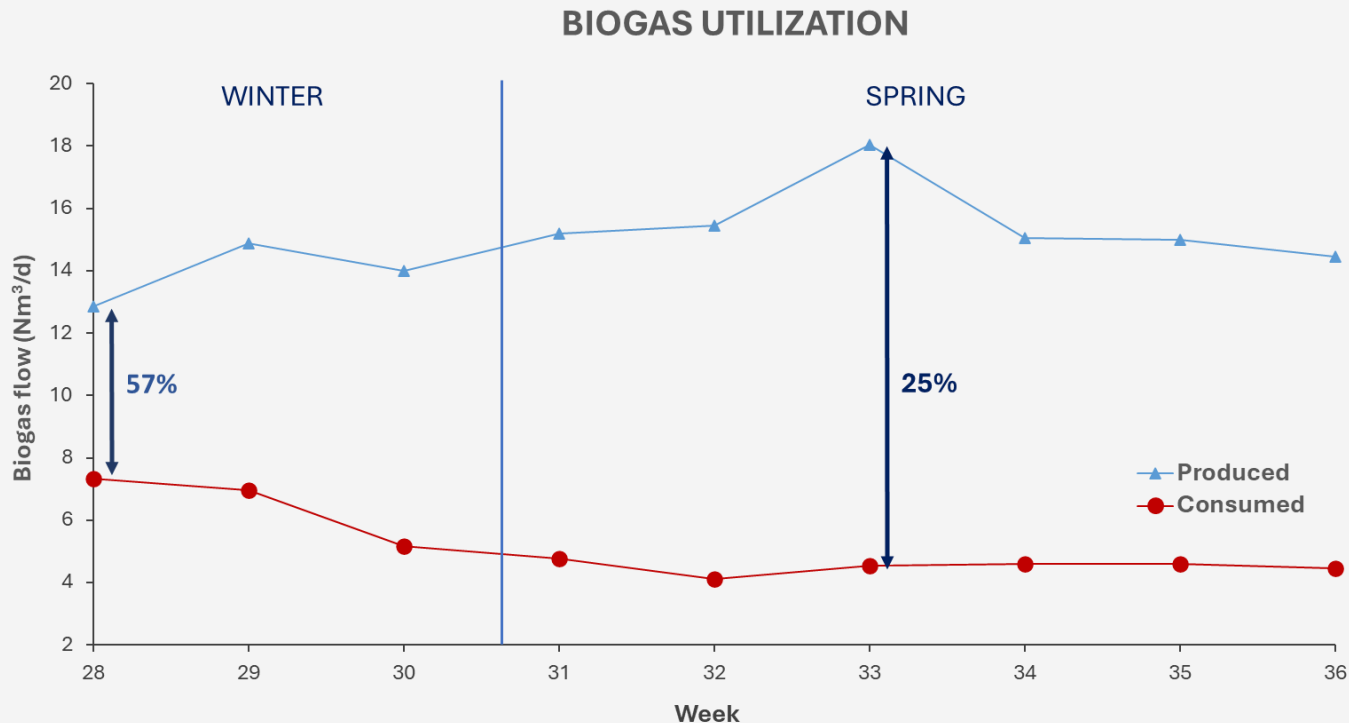
2 lamps



water heater

Specific biogas productivity = $0,25 \pm 0,2 \text{ Nm}^3/\text{m}^3.\text{d}$

Biogas utilization



**Replacement
of 26 kg of
LPG per week**



NETUM
Farmers and their families
Partners
Paola Curbelo y Luciana Varela
RedBioLAC





Thank you!

MSc. Qco. Guillermo Zinola
guillermo.zinola@utec.edu.uy



Instituto Nacional de
Tecnología Agropecuaria
Argentina

