MINISTERIO DE PRODUCCIÓN SOSTENIBLE, MEDIO AMBIENTE Y AGUA
VICEMINISTERIO DE SEGURIDAD HÍDRICA, AGUA, SANEAMIENTO BÁSICO Y RIEGO

cooperación alemana DEUTSCHE ZUSAMMENARBEIT

Cofinanciado por la Unión Europea

Implementada por: giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH



# Dr. Jaime Martí-Herrero

Doctor en Ciencias Físicas por la Universidad Nacional de Educación de España e investigador especializado en bioenergía y aprovechamiento de residuos orgánicos. Actualmente, se desempeña como Director de la Carrera de Electromecánica y Energías Renovables de la Universidad Regional Amazónica IKIAM, en Ecuador.

Ikiam Universidad Regional Amazónica

CIMNE EXCELENCIA SEVERO OCHOA

Red BioLAC Red de Biodigestores para Latino América y el Caribe

# FORO NACIONAL
## DE APROVECHAMIENTO ENERGÉTICO DE RESIDUOS



# Digestión anaerobia en LAC

## Antecedentes y perspectivas

Expositor: Jaime Martí Herrero  Fecha 27/10/2026

MINISTERIO DE PRODUCCIÓN SOSTENIBLE, MEDIO AMBIENTE Y AGUA
VICEMINISTERIO DE SEGURIDAD HÍDRICA, AGUA, SANEAMIENTO BÁSICO Y RIEGO

cooperación alemana DEUTSCHE ZUSAMMENARBEIT
Cofinanciado por la Unión Europea
Implementada por: giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH





# Biodigestores complejizados




BDG sofisticados- alto requerimiento tecnológico
CSTR
35ºC
Mezcla
Pretratamiento
mecánico



## BDG sofisticados- alto requerimiento tecnológico

Altos costes de inversión

Alta eficiencia volumétrica

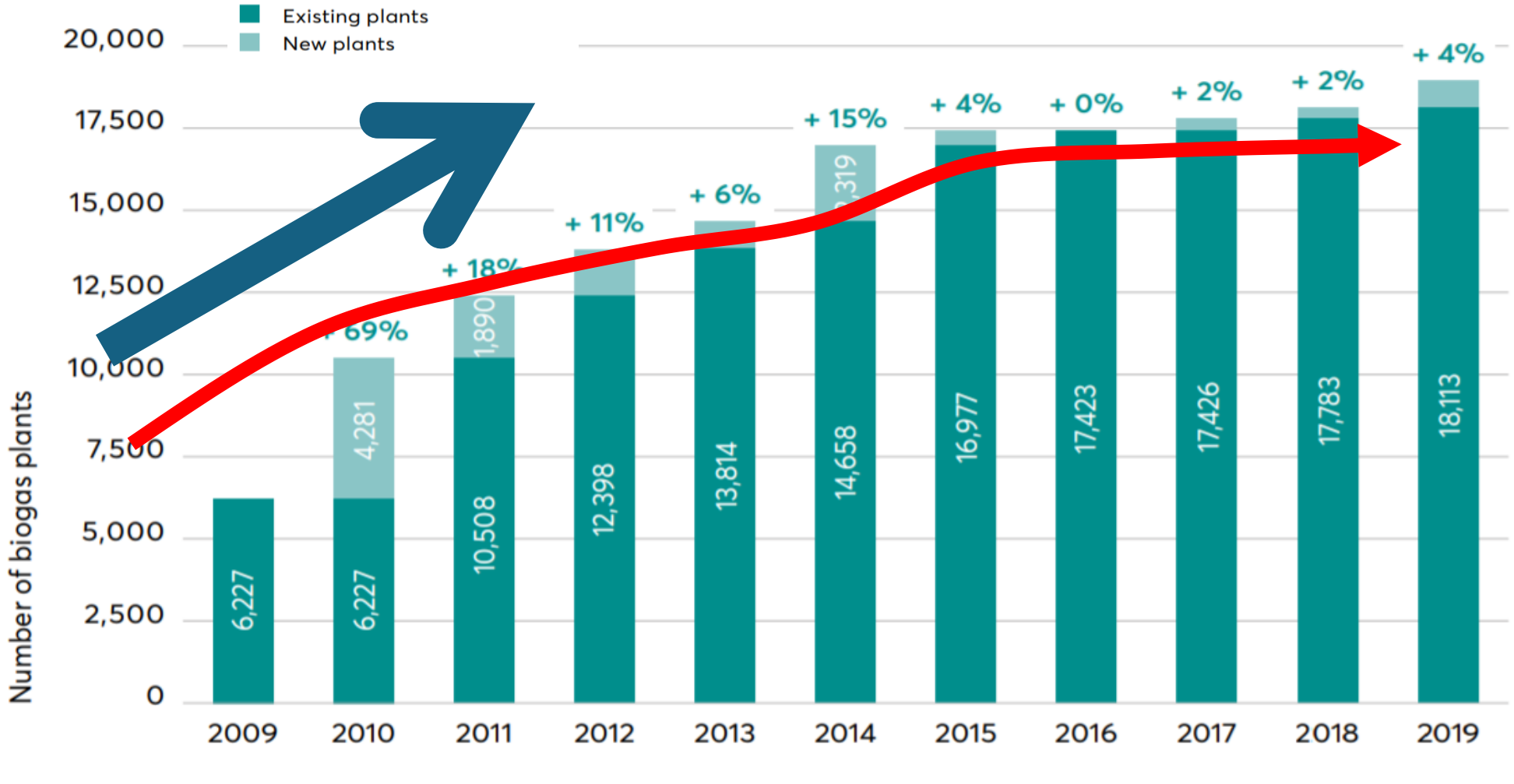
Centralización

Enfocado a electricidad

Tecnologías sofisticadas - alto input tecnológico

EBA Statistical Report 2020

Development of the number of biogas plants in Europe, 2009-2019




EBA
European Biogas Association

Tras cambios en política subsidios, el sector cae

# 2013

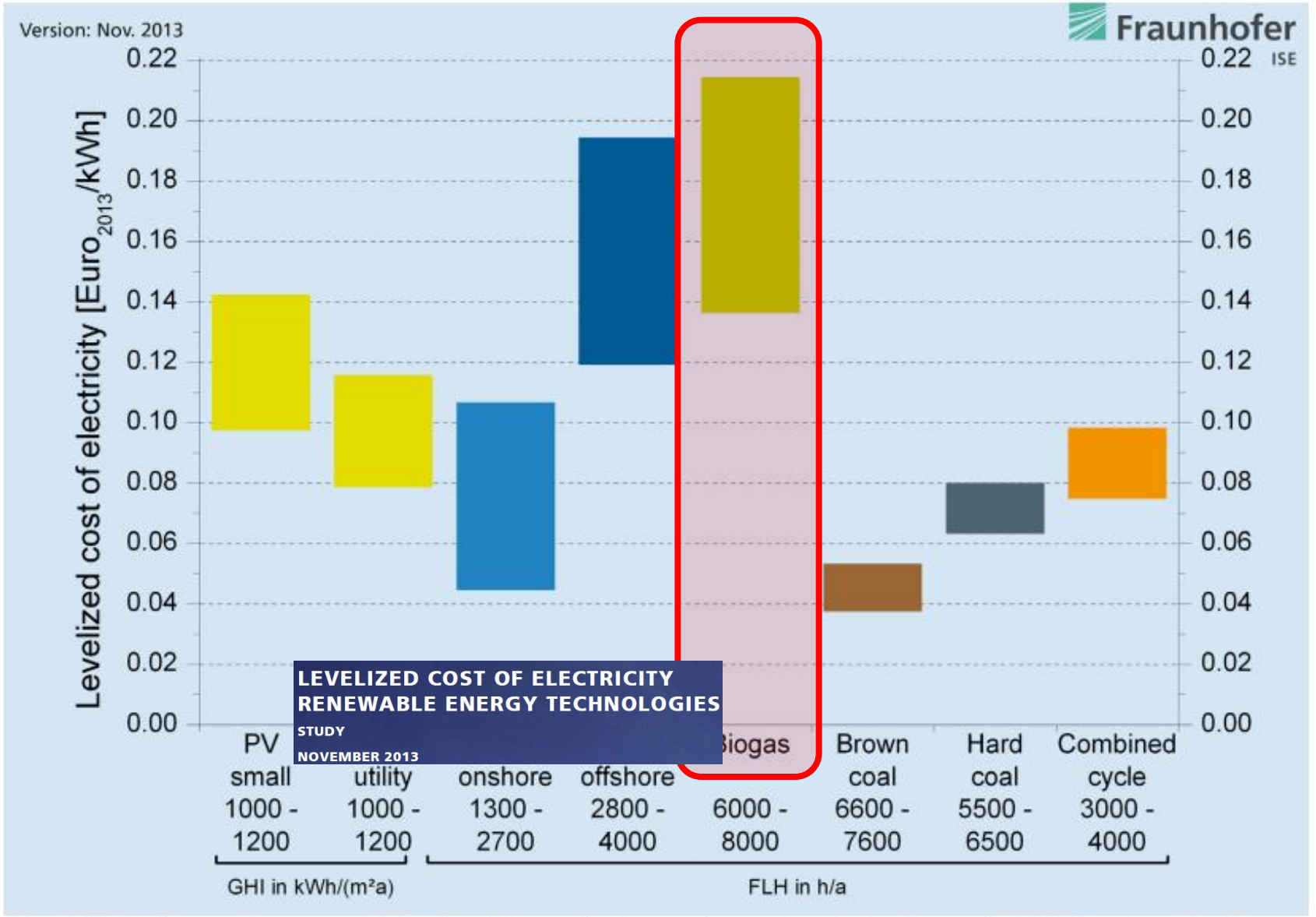
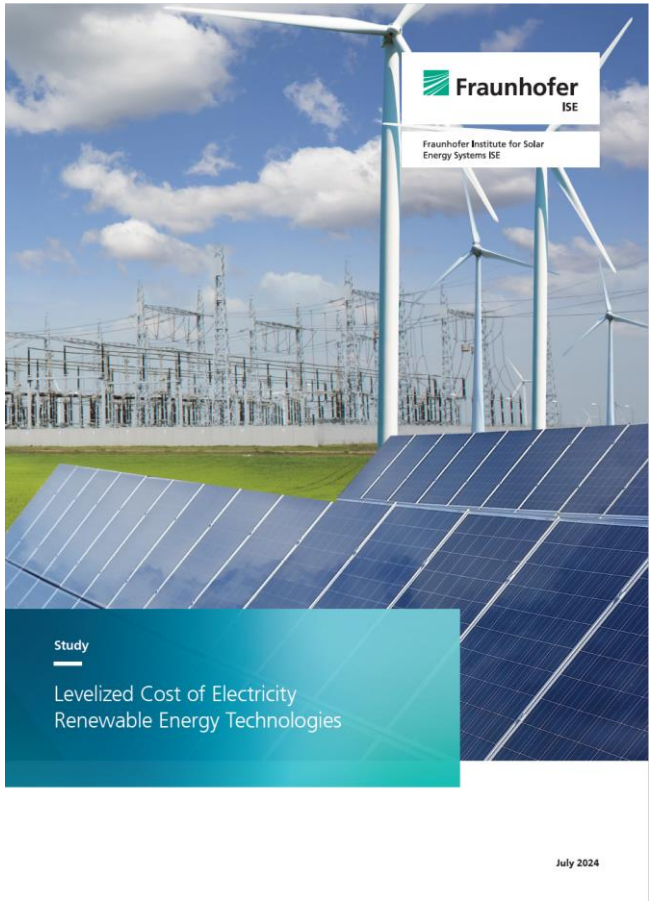



*Figure 6: LCOE of renewable energy technologies and conventional power plants at locations in Germany in 2013. The value under the technology refers in the case of PV to solar irradiation (GHI) in kWh/(m²a); in the case of other technologies it reflects the number of FLH of the power plant per year. Specific investments are taken into account with a minimum and maximum value for each technology. Additional assumptions are presented in Table 3-7.*

Otras renovables producen mejor (solo!) electricidad

# 2024



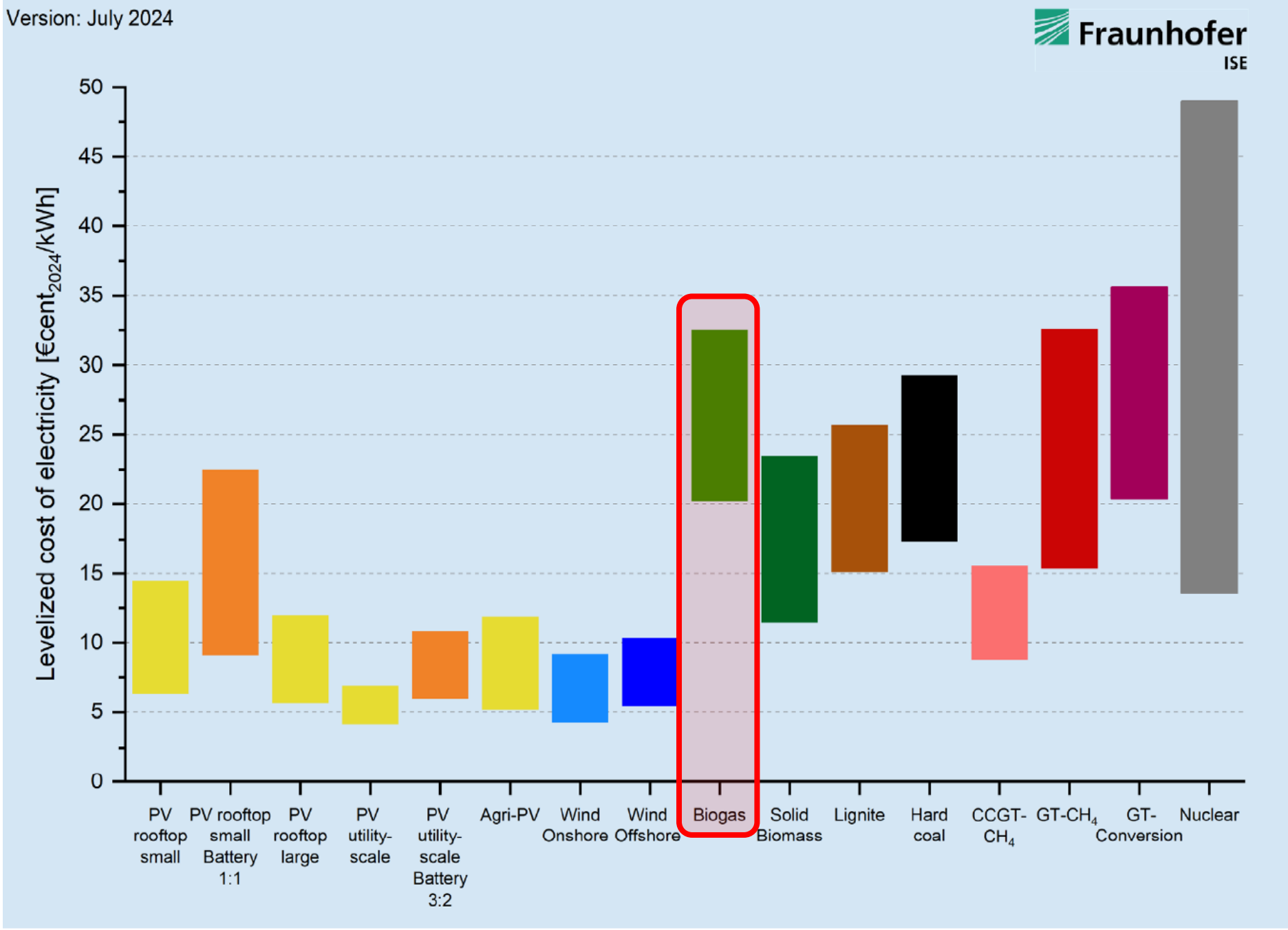
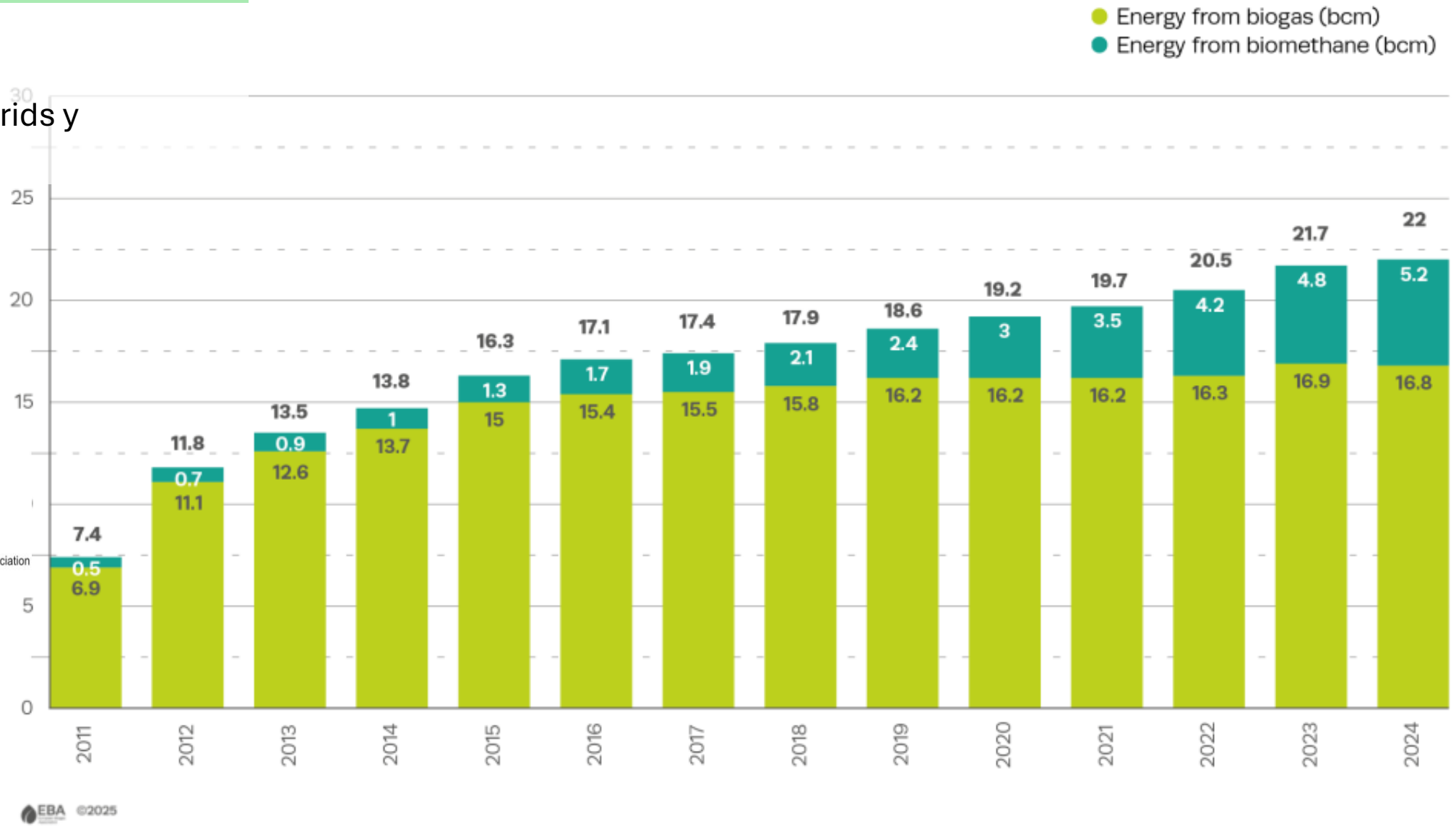




*Figure 1: LCOE of renewable energy technologies and conventional power plants at locations in Germany in 2024. Specific investments are considered using a minimum and maximum value for each technology.*

# *Combined biomethane and biogas production in Europe (bcm)*

Europa apuesta por biometano

Uso en NLG-Grids y transporte




EBA
European Biogas Association

EBA ©2025









# Biodigestores simplificados



"Just right technology"

T ambiente
Sin mezcla (o manual)
<3-4%ST




Low cost tubular digesters as appropriate technology for widespread application: Results and lessons learned from Bolivia

Jaime Martí-Herrero [a, *], Maria Chipana [b], Carlos Cuevas [b], Gabriel Paco [c], Victor Serrano [d], Bernhard Zymla [e], Klas Heising [e], Jaime Sologuren [b], Alba Gamarra [f]

*J. Martí-Herrero et al. / Renewable Energy 71 (2014) 156–165*


ARODRIGO




FEDEPAC SANTA MONICA 28% PREMIUM
FEDEPAC SANTA MONICA 28% PREMIUM
FEDEPAC SANTA MONICA 28% PREMIUM
FEDEPAC SANTA MONICA 28% PREMIUM
FEDEPAC SANTA MONICA 28% PREMIUM
FEDEPAC SANTA MONICA 28% PREMIUM
FEDEPAC SANTA MONICA 28% PREMIUM

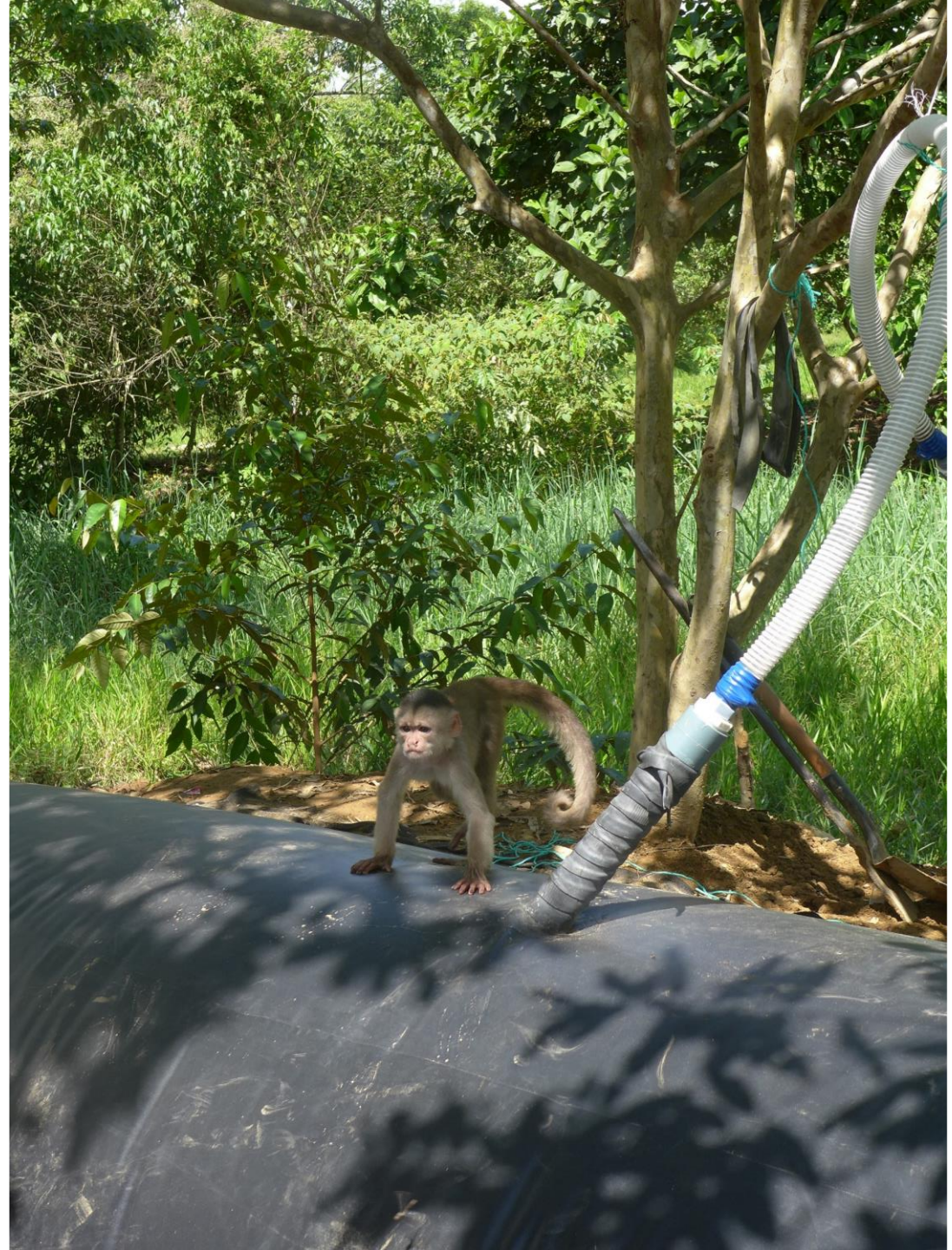












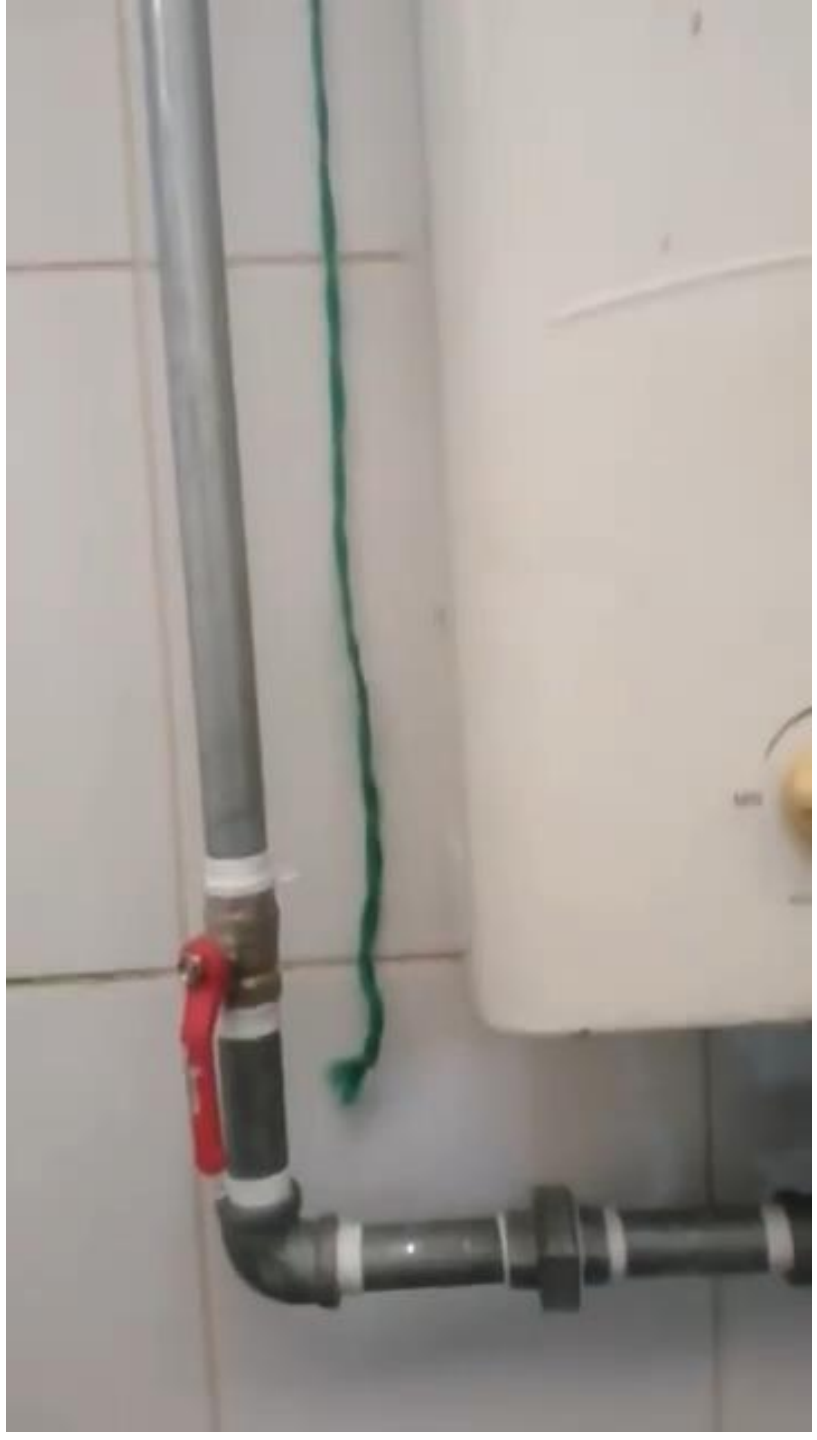

Ingeniería
Sin Fronteras


PREMIUM



Santander, Finca TOSOLY, Colombia, 2015







CIB3, La Paz, UMSA-HIVOS-CIMNE Bolivia, 2015




Viacha, La Paz, Bolivia. Hivos and CIMNE, 2014



Viacha, La Paz, Bolivia. Hivos and CIMNE, 2014



**Se puede lograr una T en el bdg similar a T máxima ambiente**

Bioresource Technology 124 (2012) 259–268

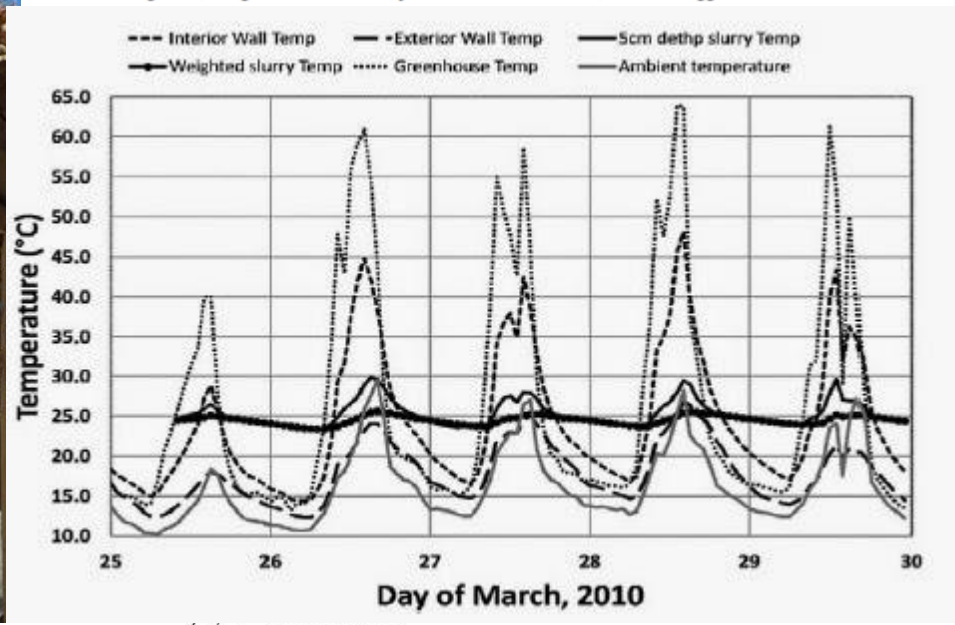
Contents lists available at SciVerse ScienceDirect

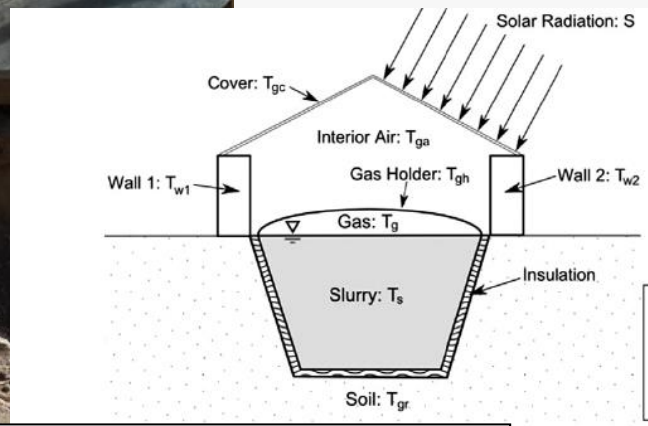
Bioresource Technology

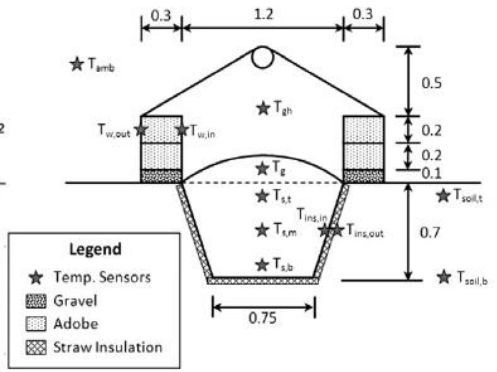
journal homepage: www.elsevier.com/locate/biortech

# Towards thermal design optimization of tubular digesters in cold climates: A heat transfer model

Thibault Perrigault [a], Vergil Weatherford [b], Jaime Martí-Herrero [a,*], Davide Poggio [c]




CIB3, La Paz, UMSA-HIVOS-CIMNE Bolivia, 2013

al computer model and locations of the temperature sensors in and around the experimental digester.

Sustainable Energy & Fuels

ROYAL SOCIETY OF CHEMISTRY

giz

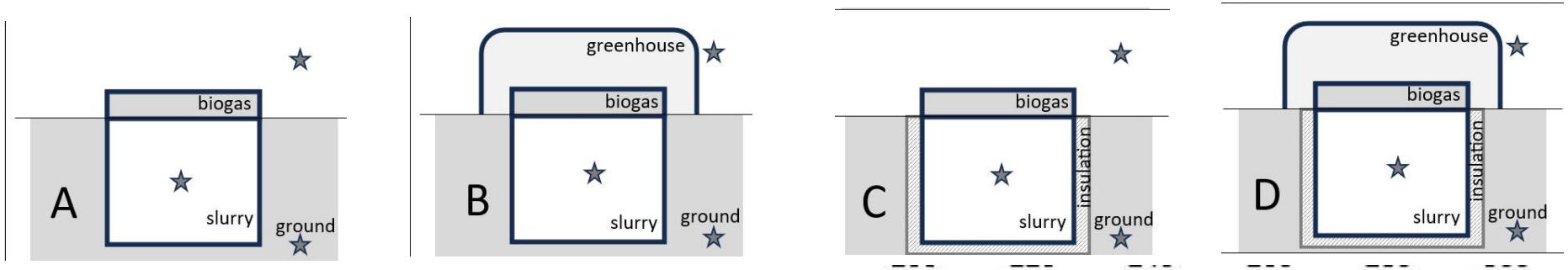
PAPER https://doi.org/10.1039/D5SE00441A

Check for updates

Cite this: *Sustainable Energy Fuels*, 2025, **9**, 4133

# Integration of solar passive heating strategies in low-cost biogas plants

Juan Jaramillo,[a] Liliana Castro,[a] Humberto Escalante[a] and Jaime Martí-Herrero *[bc]




| | | scenario | | | | |
|---|---|---|---|---|---|---|
| digester | Ts-Tamb [°C] | A1 | B1 | C1 | C2 | D1 |
| | A1 | **+3.0 °C** | +3.2 °C | +4.2 °C | +5.7 °C | +7.3 °C |
| | B1 | +0.7 °C | **+0.7 °C** | +2.5 °C | +4.5 °C | +5.3 °C |
| | C1 | +2.3 °C | +2.3 °C | **+4.3 °C** | +6.9 °C | +7.6 °C |
| | C2 | +3.1 °C | +3.3 °C | +4.1 °C | **+5.5 °C** | +7.2 °C |
| | D1 | +5.1 °C | +5.4 °C | +6.2 °C | +7.5 °C | **+9.4 °C** |
| **Mean Slurry T increment** | | **+2.8 °C** | **+3.0 °C** | **+4.3 °C** | **+6.0 °C** | **+7.4 °C** |

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

# Evaluation of the low technology tubular digesters in the production of biogas from slaughterhouse wastewater treatment

J. Martí-Herrero [a, b, *], R. Alvarez [c], T. Flores [d]

https://doi.org/10.1016/j.jclepro.2018.07.148

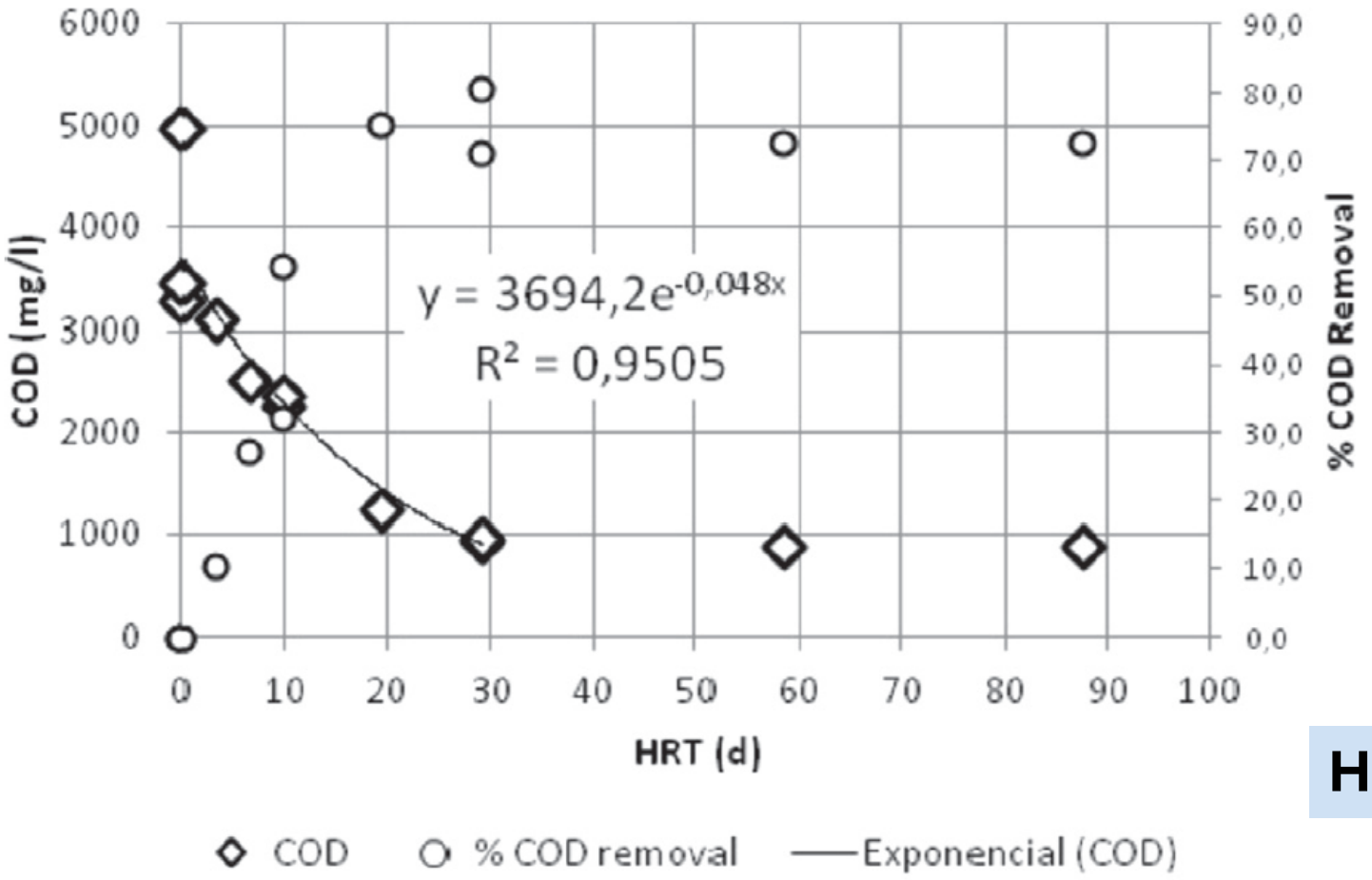
**Tres biodigestores en serie, el primero con botellas**

***+ biofilm que Aumento de SRT***



**Fig. 1.** The three tubular digesters in series, monitored in the Cochabamba slaughterhouse, at 2572 m above sea level (Martí-Herrero et al., 2016).

**Límite en la remoción de DQO (75%; 20d)**




**Hace falta humedal**

**Fig. 4.** COD and %COD removal of SWW for different HRTs, using sequenced tubular digesters. The COD values for HRT = 0 d correspond to SWW before entering the digester system.

Journal of Water Process Engineering 69 (2025) 106797

Contents lists available at ScienceDirect

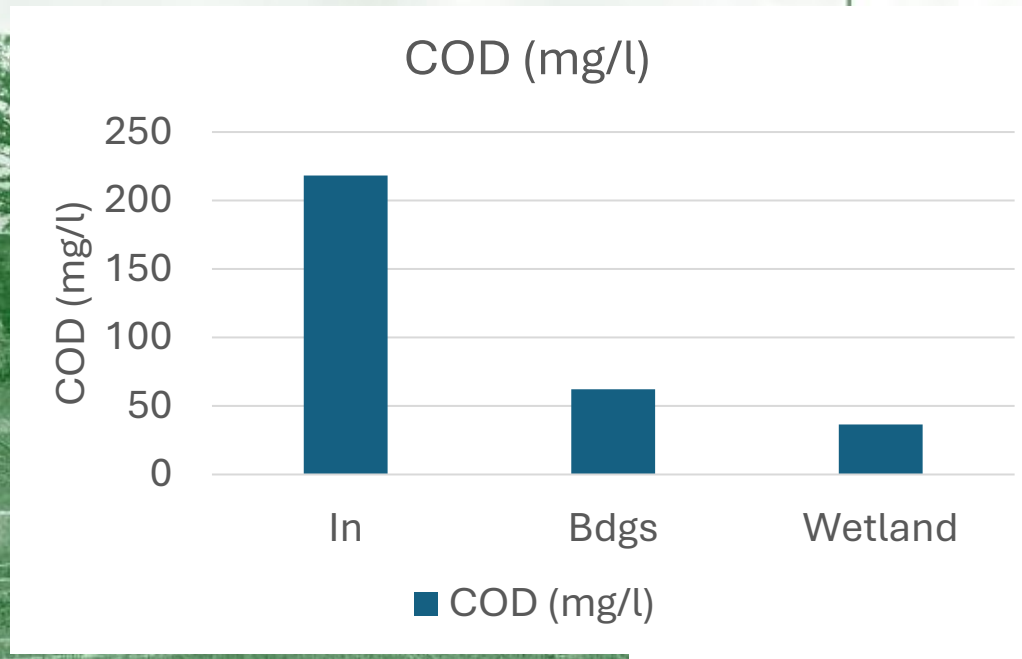
Journal of Water Process Engineering

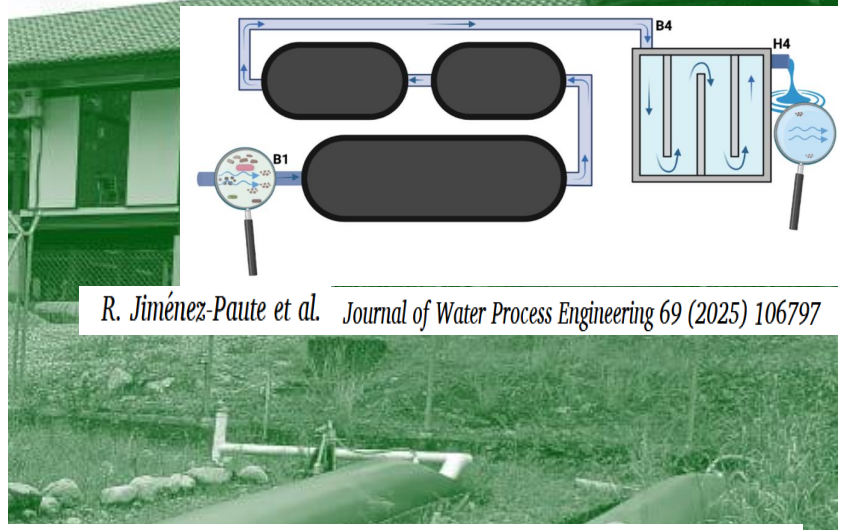
journal homepage: www.elsevier.com/locate/jwpe

# Performance of a low-cost full-scale wastewater treatment system: Tubular digesters combined with granular filtration for domestic wastewater in the Ecuadorian Amazon

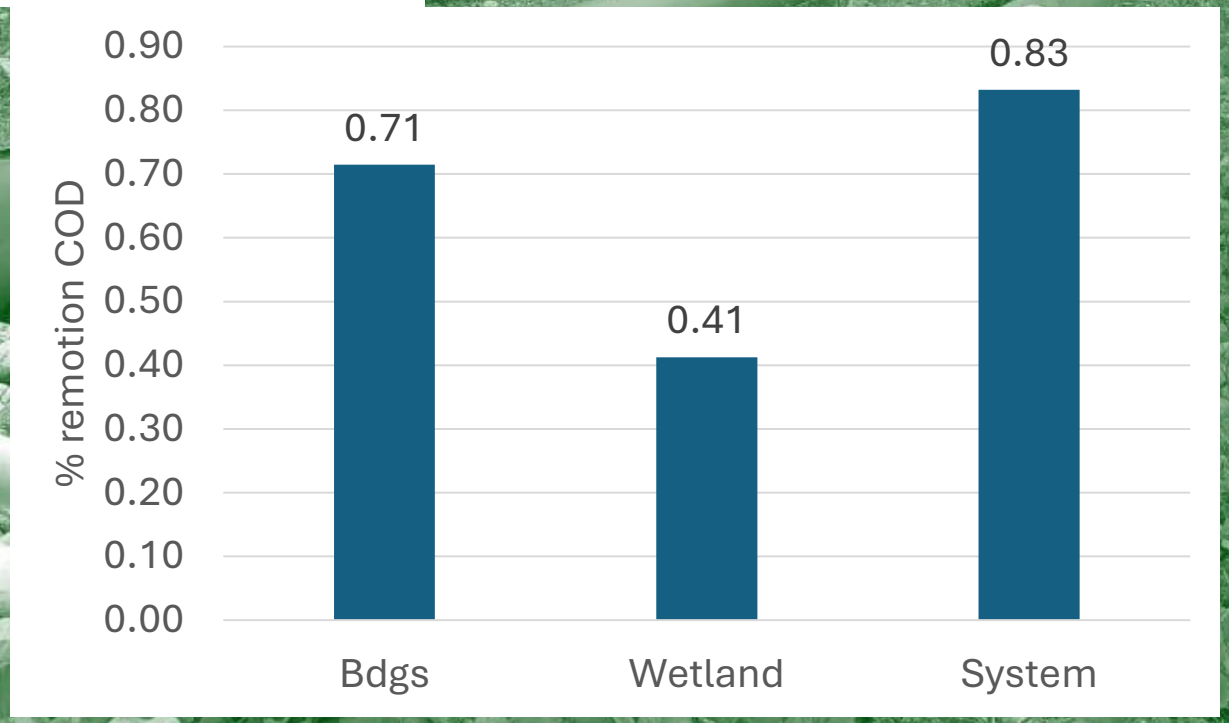
Rocio Jiménez-Paute [a,b,*], Marcos Hidalgo [b], Diana Guaya [c], Jaime Martí-Herrero [a,d,**]




COD (mg/l)
250
200
150
100
50
0
COD (mg/l)
In
Bdgs
Wetland
COD (mg/l)


B4
H4
B1
R. Jiménez-Paute et al.
Journal of Water Process Engineering 69 (2025) 106797




0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
% remotion COD
0.71
0.41
0.83
Bdgs
Wetland
System



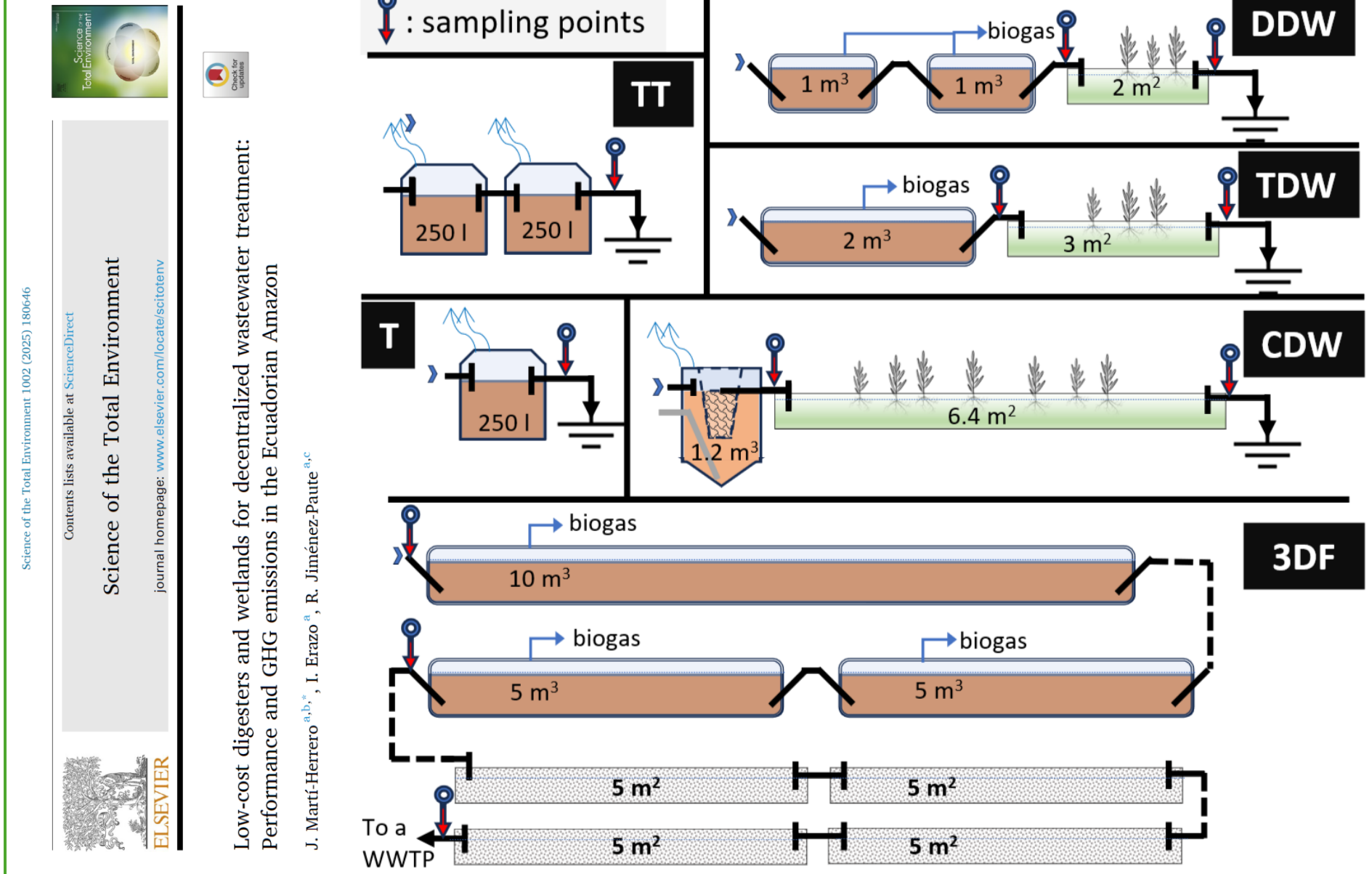




Ikiam
Universidad Regional Amazónica


tigo


biogas
1 m3
1 m3
2 m2
DDW




Science of the Total Environment 1002 (2025) 180646

Contents lists available at ScienceDirect

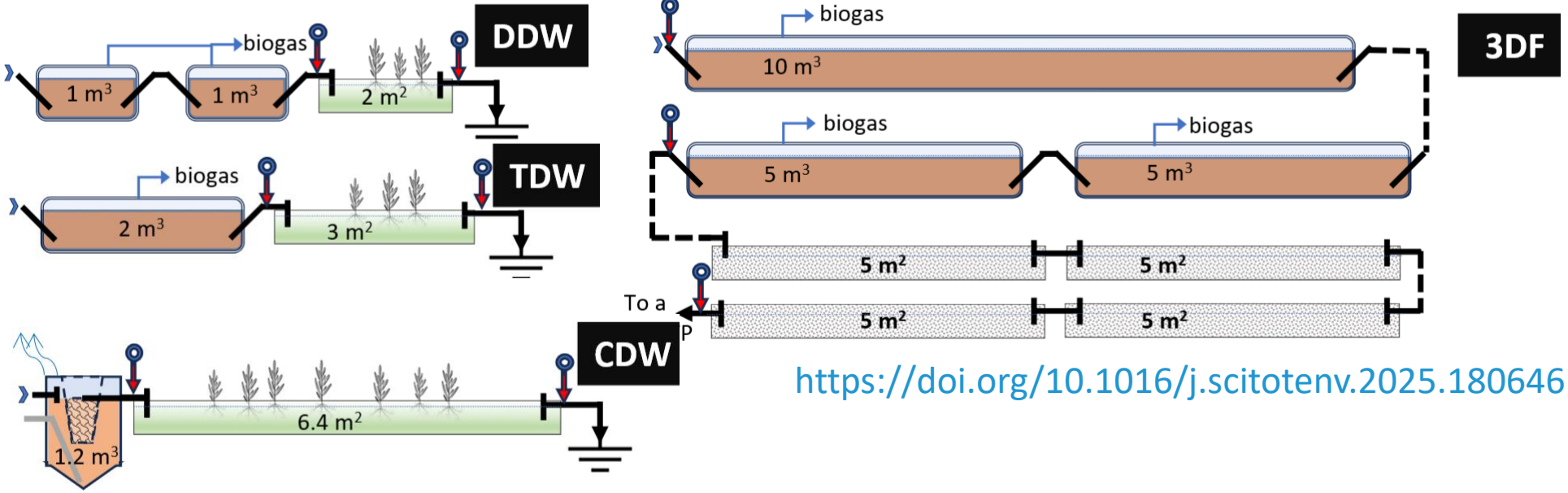
Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Low-cost digesters and wetlands for decentralized wastewater treatment: Performance and GHG emissions in the Ecuadorian Amazon

J. Martí-Herrero [a,b,*], I. Erazo [a], R. Jiménez-Paute [a,c]

Low-Cost Tubular Digesters and Constructed Wetlands for Decentralized Wastewater Treatment: Performance, Biogas Potential, and Emissions in Rural Amazonian Ecuador J. Martí-




https://doi.org/10.1016/j.scitotenv.2025.180646

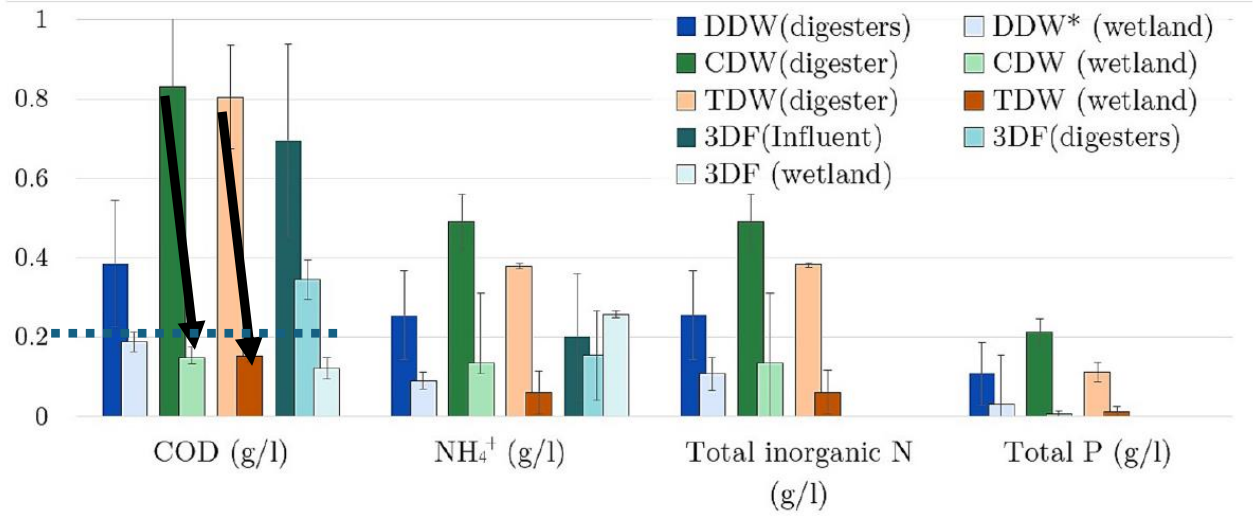



**Fig. 6.** Chemical characterization of the effluent from the household scale systems that have digest , CDW, TDW), and the institutional system (3DF) that have three digesters in series followed by a granular is also available. For DDW* only Case A from Table 1 has been considered, due case B shows high SD, indicating variable performance of the wetland.

Los bdgs secuenciales mejor

Tamaño de humedal



UPeU
UNIVERSIDAD PERUANA UNION

Ikiam
Universidad Regional Amazónica

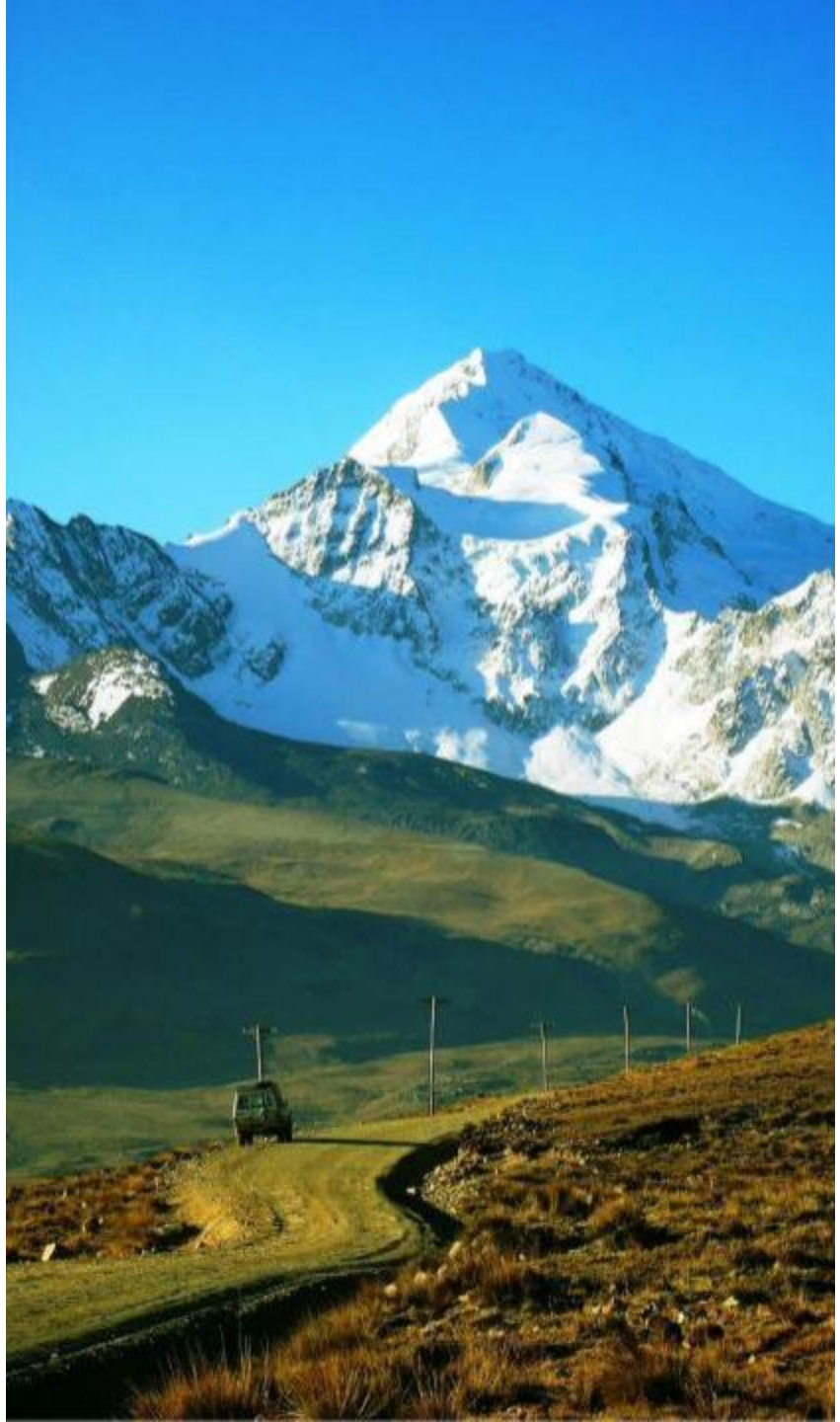
CIMNE
EXCELENCIA SEVERO OCHOA







Ikiam
Universidad Regional Amazónica





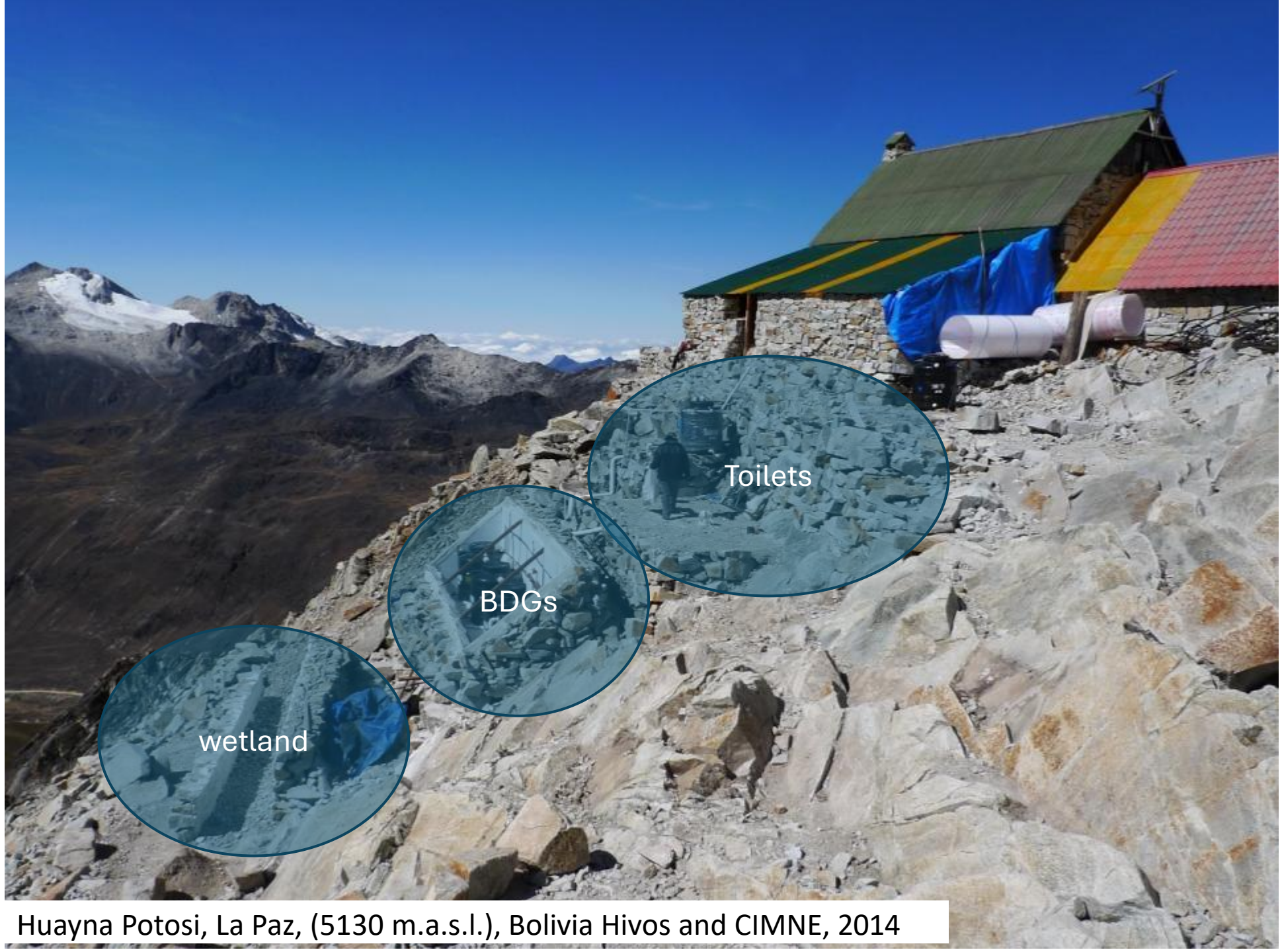


**La PTAR (y biodigestores) mas altos del mundo**




ROCK CAMP
CAMPO·ALTO ROCA·
5130masl.






Huayna Potosi, La Paz, (5130 m.a.s.l.), Bolivia Hivos and CIMNE, 2014




Huayna Potosi, La Paz, (5130 m.a.s.l.), Bolivia Hivos and CIMNE, 2014




Huayna Potosi, La Paz, (5130 m.a.s.l.), Bolivia Hivos and CIMNE, 2014


2024






Huayna Potosi, La Paz, Bolivia









Huayna Potosi, La Paz, Bolivia






giz

Huayna Potosi, La Paz, Bolivia






Energy Conversion and Management 261 (2022) 115670

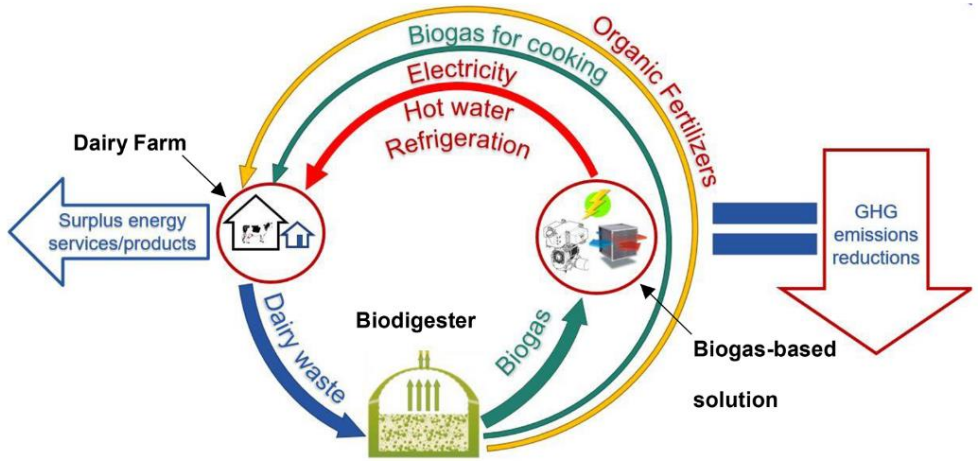
Contents lists available at ScienceDirect

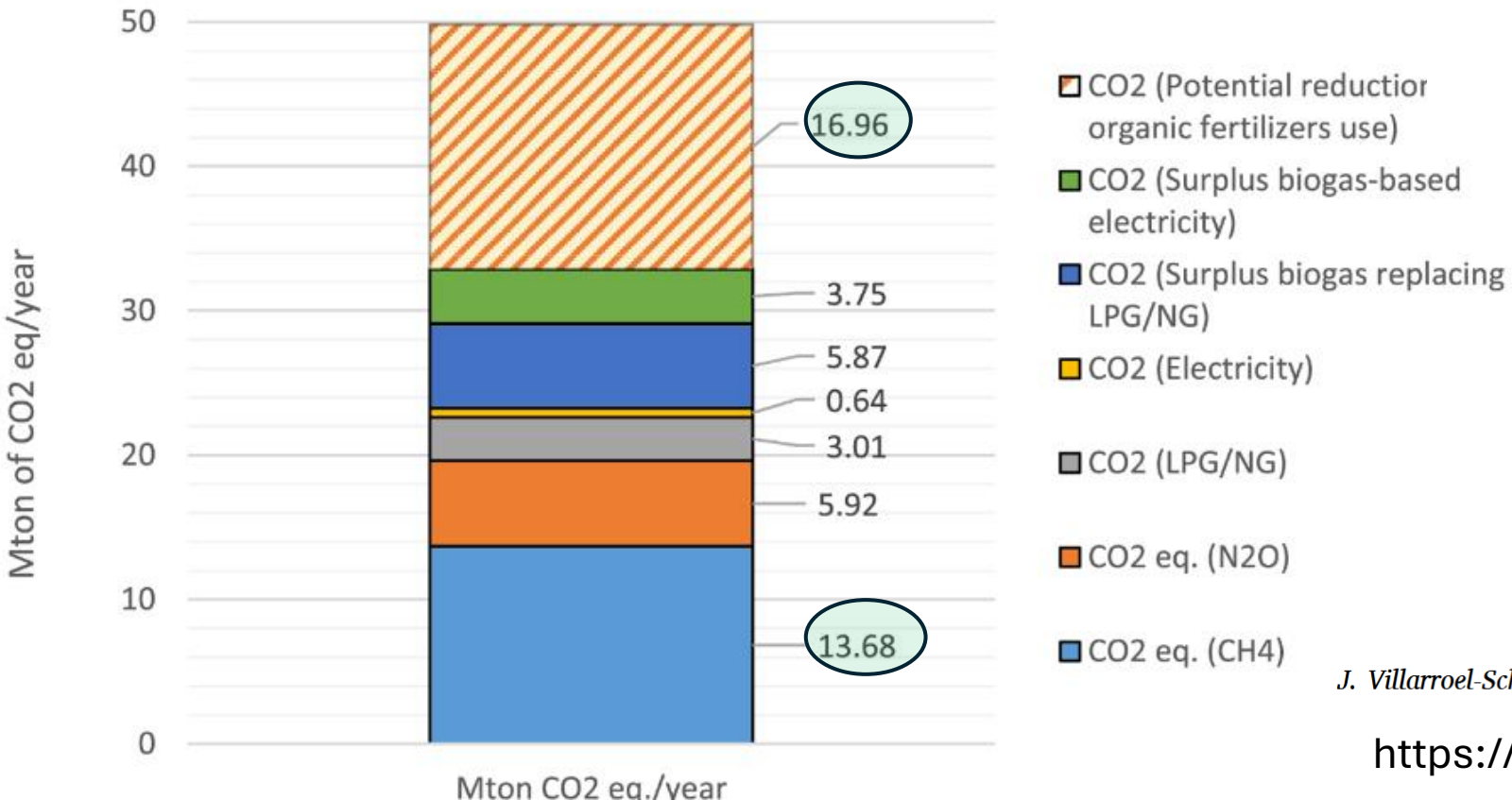
Energy Conversion and Management

journal homepage: www.elsevier.com/locate/enconman

# Energy self-sufficiency and greenhouse gas emission reductions in Latin American dairy farms through massive implementation of biogas-based solutions

J. Villarroel-Schneider [a,b,*], Lena Höglund-Isaksson [c], Brijesh Mainali [d], J. Martí-Herrero [e,f], Evelyn Cardozo [b], Anders Malmquist [a], Andrew Martin [a]




*J. Villarroel-Schneider et al. Energy Conversion and Management 261 (2022) 115670*

https://doi.org/10.1016/j.enconman.2022.115670



**3000**

**cerdos**

# Y a los grandes productores



3000





3000
cerdos

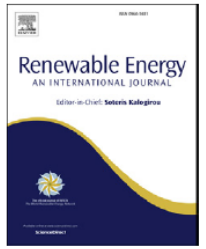


J. Martí-Herrero et al. / Renewable Energy 133 (2019) 676–684

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene




**100-150l de biogas por kg fresco de FVW**

# Biogas from a full scale digester operated in psychrophilic conditions and fed only with fruit and vegetable waste

J. Martí-Herrero [a, b, *], G. Soria-Castellón [c], A. Diaz-de-Basurto [d], R. Alvarez [e], D. Chemisana [f]

**Table 1**
Composition of FVW.

| Material | % |
|---|---|
| Citrus | 21.47 |
| Onion/garlic | 13.52 |
| Stems and leaves | 5.83 |
| Potato | 4.47 |
| Banana | 4.59 |
| Tomato/pepper | 4.32 |
| Bean/pea | 4.28 |
| Parsley | 2.18 |
| Corn | 1.93 |
| Salad | 1.86 |
| cactus pear | 1.83 |

**21% de cítricos**
**pH 5.4**
**28 %ST**

**Table 2**
Characterization of the FVW.

| Parameter (unit) | FVW (Standard deviation) |
|---|---|
| Mean volumetric weight (kg/m$^3$) | 352 (64.7) |
| pH | 5.38 (0.01) |
| Total solids (TS) (%) | 27.96 (7.27) |
| Volatile solids (VS) (%) w.w. | 26.32 (1.27) |
| Volatile solids (%TS) d.w | 94.13 (0.35) |
| Organic carbon (%TS) | 54.60 (0.20) |
| Total Nitrogen (%TS) | 1.80 (0.10) |
| Total phosphorus (%TS) | 0.55 (0.09) |
| Total Potassium (%TS) | 2.43 (0.24) |
| Ammonium (%TS) | 0.21 (0.04) |
| C/N | 30.38 (1.85) |

UPeU
UNIVERSIDAD PERUANA UNION

Ikiam
Universidad Regional Amazónica

CIMNE
EXCELENCIA SEVERO OCHOA





Renewable Energy 273 (2026) 126077

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene



# Cattle manure biochar as an additive to improve methane production from cheese whey in rural areas

Glen Madrigal [a], German Mamani-Cachicatari [a], Oscar Mendieta [b,*], Jaime Martí-Herrero [c,d,**]





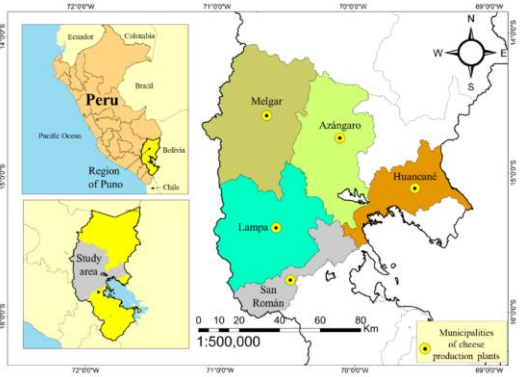



Fig. 1. Geographic distribution of the five cheese-producing factories selected for the study in the Puno region, Peru.

**Table 7**
Results of the energy potential of anaerobic digestion technology integration in cheese production factories in Puno, Peru.

| Cheese factory ($i$) | | A | H | L | M | SR |
|---|---|---|---|---|---|---|
| $E_i$ (MJ $d^{-1}$) | | 415.8 | 432.2 | 504.5 | 626.6 | 280.9 |
| $V_{CH4\text{-}r,i}$ ($m^3$ $d^{-1}$) | | 14.05 | 14.6 | 17.05 | 21.17 | 9.49 |
| $HRT_i$ (d) | | 87.5 | 93.3 | 91.5 | 82.4 | 102.9 |
| **First-order kinetic model parameters** | $B_{max,i}$ (mL $CH_4$ $g^{-1}$ VS) | 219.01 | 187.03 | 183.36 | 262.13 | 185.36 |
| | $k_{35i}$ ($d^{-1}$) | 0.129 | 0.174 | 0.121 | 0.156 | 0.117 |
| | $k_{16i}$ ($d^{-1}$) | 0.0248 | 0.0335 | 0.0234 | 0.03 | 0.0225 |
| $SMY_i$ (mL $CH_4$ $g^{-1}$ VS) | | 309.21 | 271.46 | 265.68 | 312.71 | 252.42 |
| $V_{CH4\text{-}p,i}$ ($m^3$ $CH_4$ $d^{-1}$) | | 14.34 | 12.93 | 12.41 | 16.1 | 9.92 |
| $FRC_i$ (%) | | 102% | 88.50% | 72.80% | 76.00% | 104% |

$E_i$: energy requirement of each factory, $V_{CH4\text{-}r,i}$: methane volume required, $HRT_i$: hydraulic retention time calculated assuming the system operates six days per week, $B_{max,i}$: maximum biogas potential, $k_{35i}$: first-order kinetic constant at 35 °C, $k_{16i}$: first-order kinetic constant at 15.8 °C, $SMY_i$: specific methane yield, $V_{CH4\text{-}p,i}$: volume of methane that could be produced in each cheese factory from CW with BM-BC addition, $FRC_i$: traditional fuel replacement capacity, $i$: denotes the different cheese factories considered in the analysis.















# 2012- Ecuador

Biodigestores de max 8m3

Impulso por ONGs

No profesionales

Diseño mejorable

Limitado a trópico

# 2025- Ecuador









# 2025- Ecuador









# 2025- Ecuador









# 2025- Ecuador

- Biodigestores de hasta 4000m3
- Geomembrana (PVC o polietileno)
- Diseños adaptados a clima frio
- Profesionalización (al menos 4 empresas)



Ikiam
Universidad Regional Amazónica

CIMNE

EXCELENCIA SEVERO OCHOA

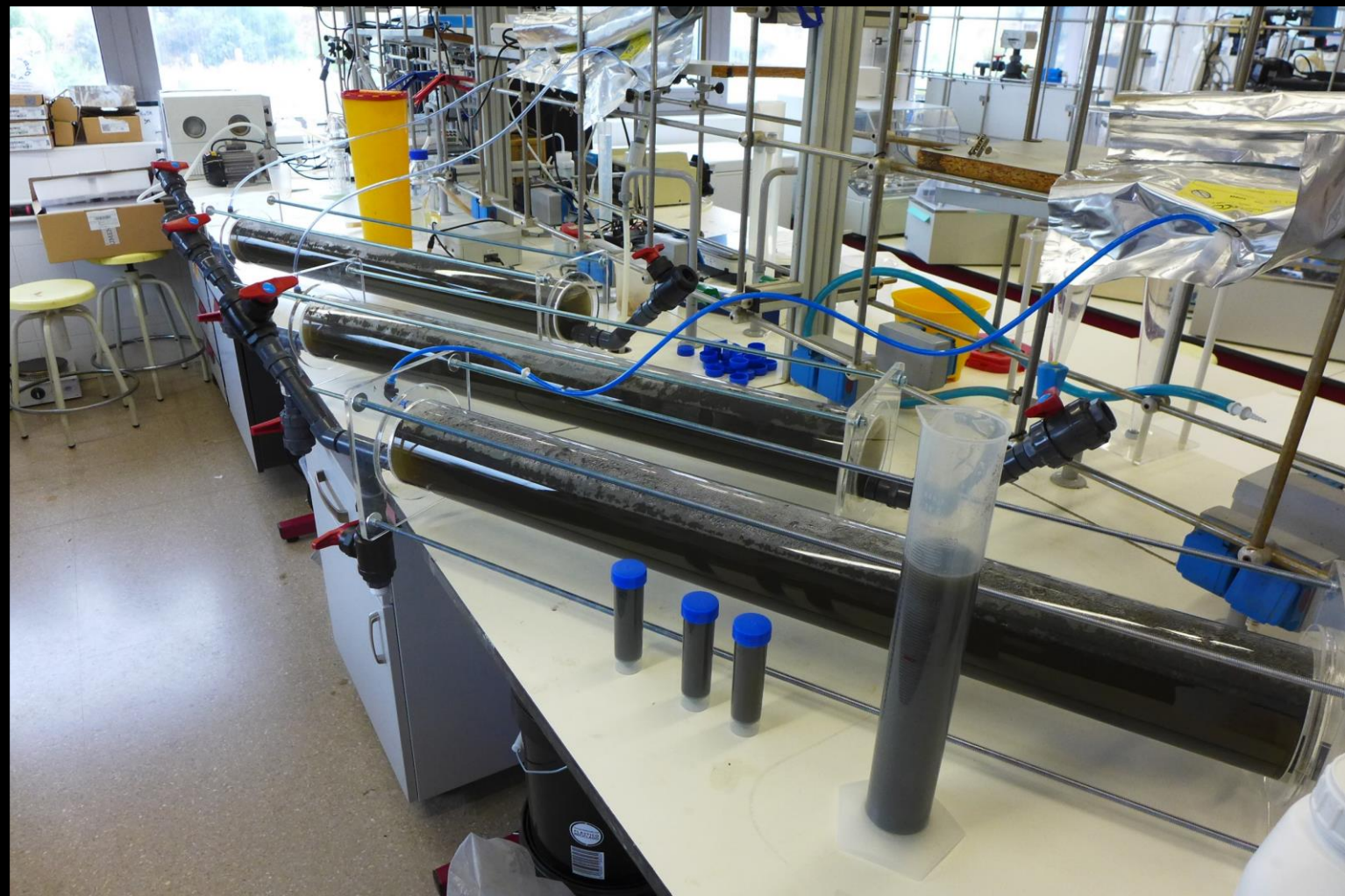
UAM
Universidad Autónoma de Madrid

Junta de Andalucía
Consejería de Agricultura, Pesca, Agua y Desarrollo Rural
ifapa.es










Ikiam
Universidad Regional Amazónica
aqualia
CIMNE
EXCELENCIA
SEVERO
OCHOA







# Conclusiones

- Ya se esta produciendo transferencia sur-norte
- Los bdg tubulares son una tecnología consolidada
  Descentralizado, fincas integrales
- La temperatura ya es un tema superado
  Calefacción solar pasiva, adaptación
- Son versátiles en sus aplicaciones
  Biomasa residual: Estiércoles, aguas residuales, residuos vegetales, etc.



# GRACIAS POR LA ATENCIÓN DISPENSADA

## Ashka pagarachu!

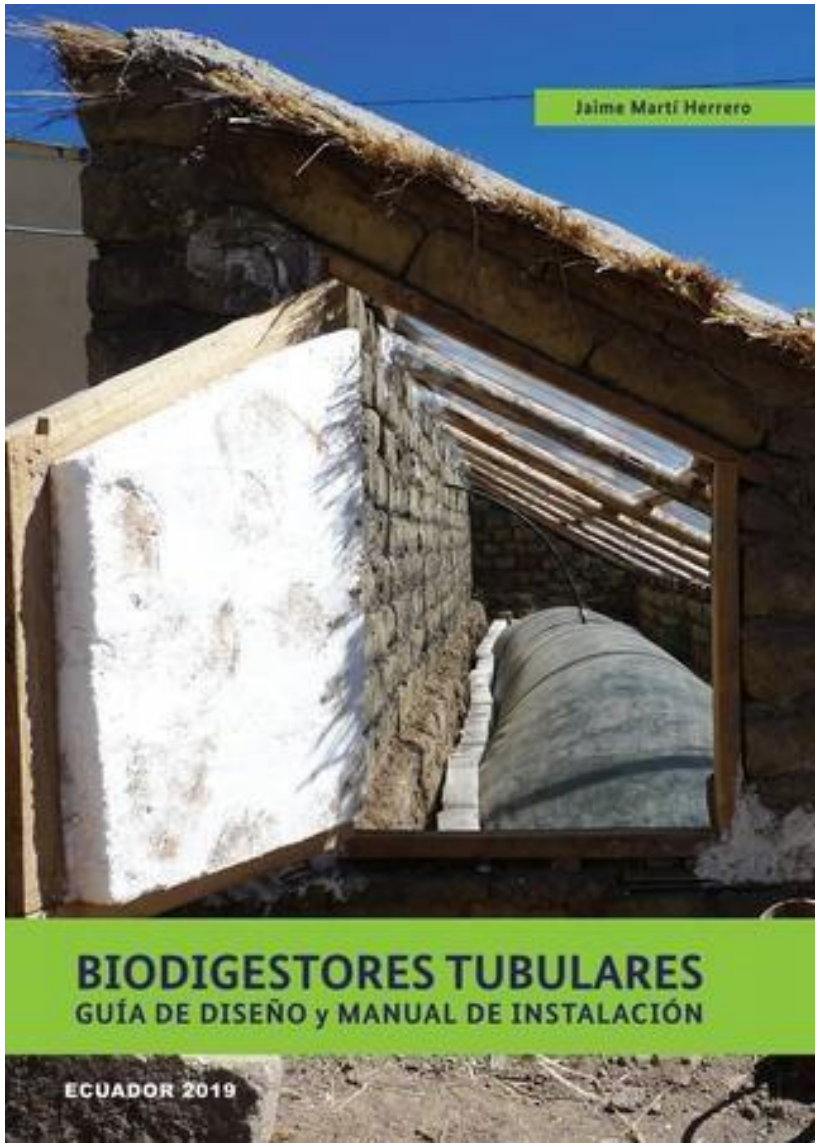
Contacto:
Jaime.marti@ikiam.edu.ec

FORO NACIONAL
DE APROVECHAMIENTO ENERGÉTICO DE RESIDUOS

Ikiam
Universidad Regional Amazónica

CIMNE
EXCELENCIA SEVERO OCHOA

Red BioLAC




PRESIDENCIA DEL ESTADO PLURINACIONAL DE BOLIVIA

MINISTERIO DE PRODUCCIÓN SOSTENIBLE, MEDIO AMBIENTE Y AGUA
VICEMINISTERIO DE SEGURIDAD HÍDRICA, AGUA, SANEAMIENTO BÁSICO Y RIEGO

cooperación alemana
DEUTSCHE ZUSAMMENARBEIT

Cofinanciado por la Unión Europea

Implementada por:
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH