Decentralized recycling of digested residues in agricultural regions: A multi-dimensional sustainability assessment

Céline Vaneeckhaute, David Styles, Thomas Prade,
Paul Adams, Gunnar Thelin, Lena Rodhe, Tina D'Hertefeldt

7th International Conference on Sustainable Solid Waste Management,
Heraklion, Greece, June 26-29, 2019

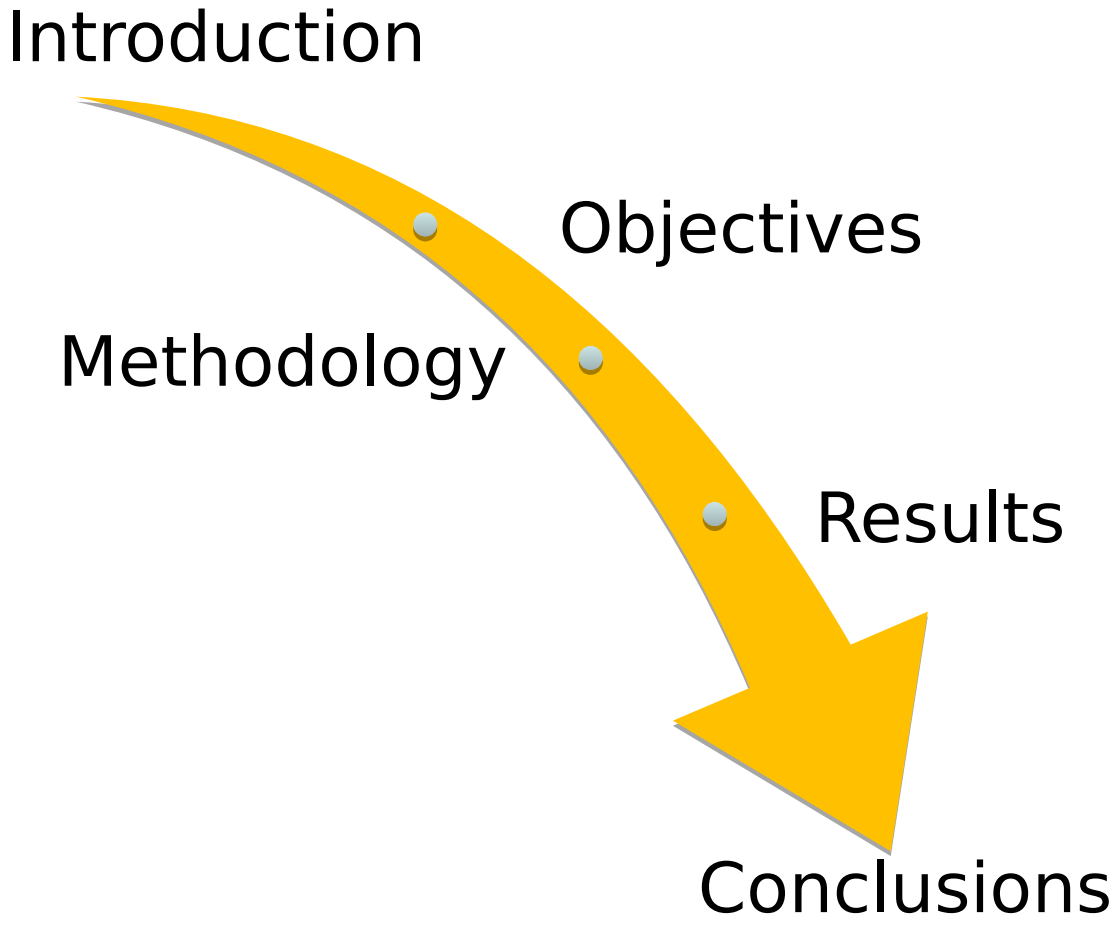
BioEngine

Institut EDS Institut Hydro-Québec en environnement, développement et société de l'Université Laval

Université Laval

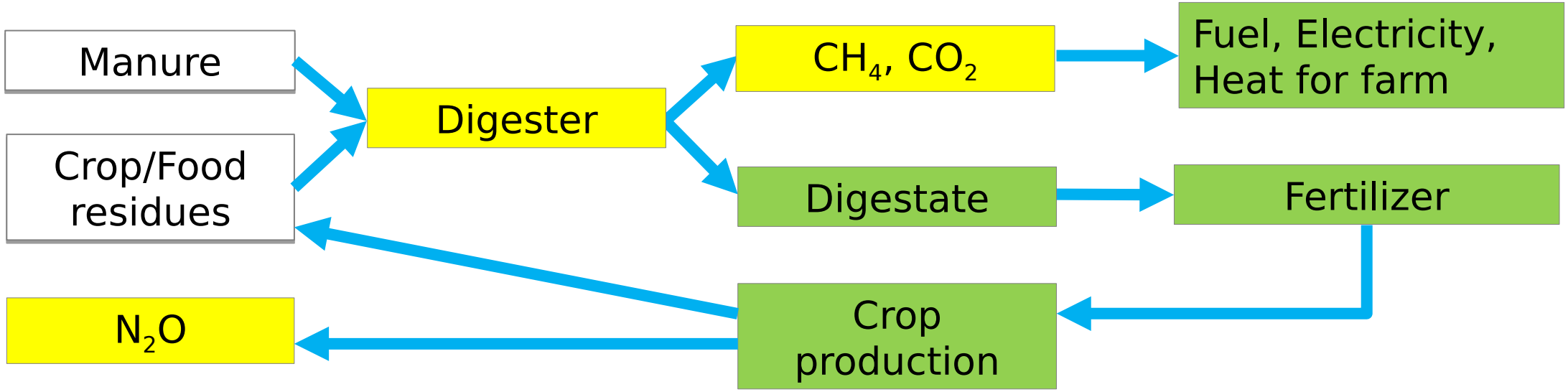
CentrEau Centre de recherche sur l'eau Water Research Centre

Outline


Introduction
Objectives
Methodology
Results
Conclusions

Introduction

Decentralized anaerobic digestion in agricultural regions



- Logistically attractive in rural areas: feedstock locally available
- Less economically attractive: non-supportive regulatory framework and lack of economic incentives for potential investors
- Lack of knowledge and quantitative studies on potential benefits

⇒ Currently < 1% of the potential benefits from anaerobic digestion is being used (EUBIA, 2017)

Introduction

Existing sustainability assessment studies (LCA)

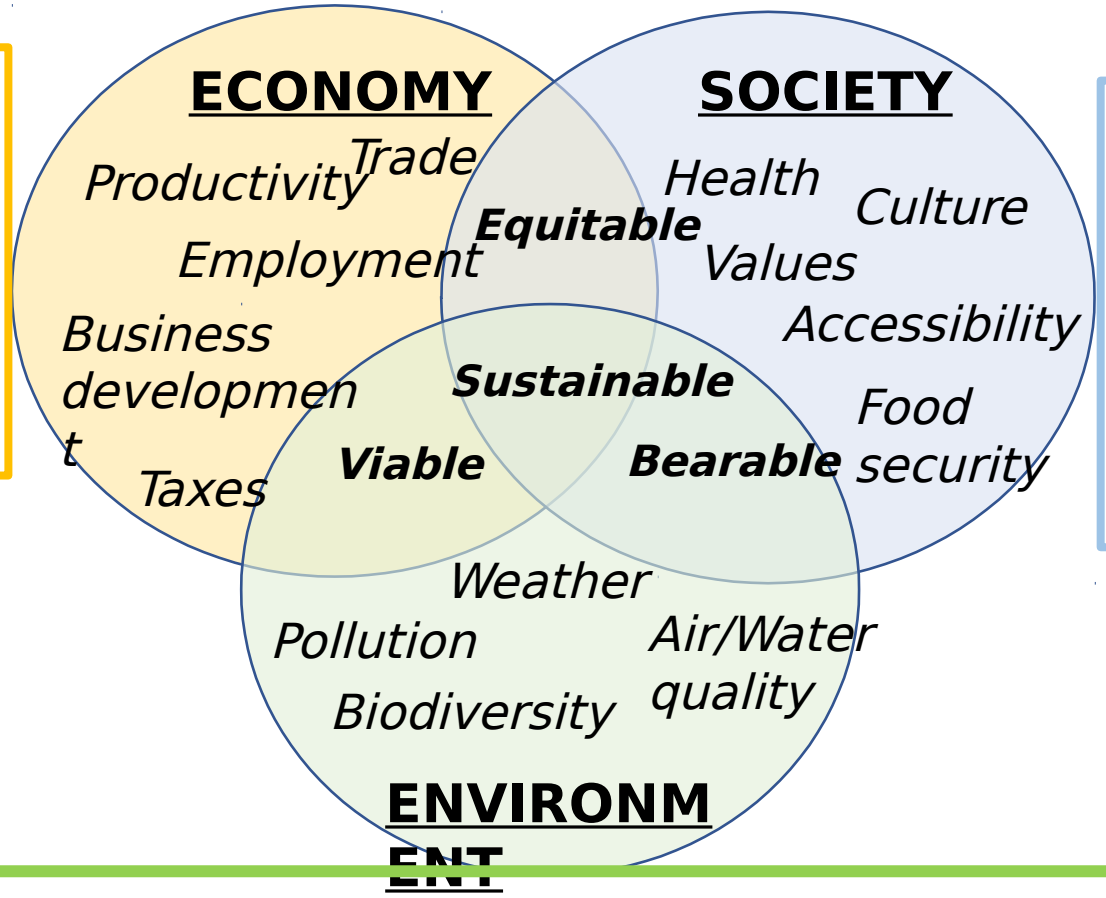
- Fertilizer replacement value of recovered nutrients not or not accurately accounted for
- Soil organic carbon effects not included
- Inconsistent representation of environmental effects related to storage of manure or digestate (GHG emissions, nutrient losses)
- Economic benefits/losses when changing farm management practices often not assessed
- Social perception in the agricultural region not assessed

⇒ Need for a holistic and multi-dimensional sustainability assessment framework

Objectives

- To identify the environmental, economic and social sustainability of using digested waste instead of raw animal manure and chemical fertilizer in decentralized agricultural regions (case study: Southern Sweden)

Net Present Value



Stakeholder perception study

Expanded Boundary Life Cycle Assessment

Methodology

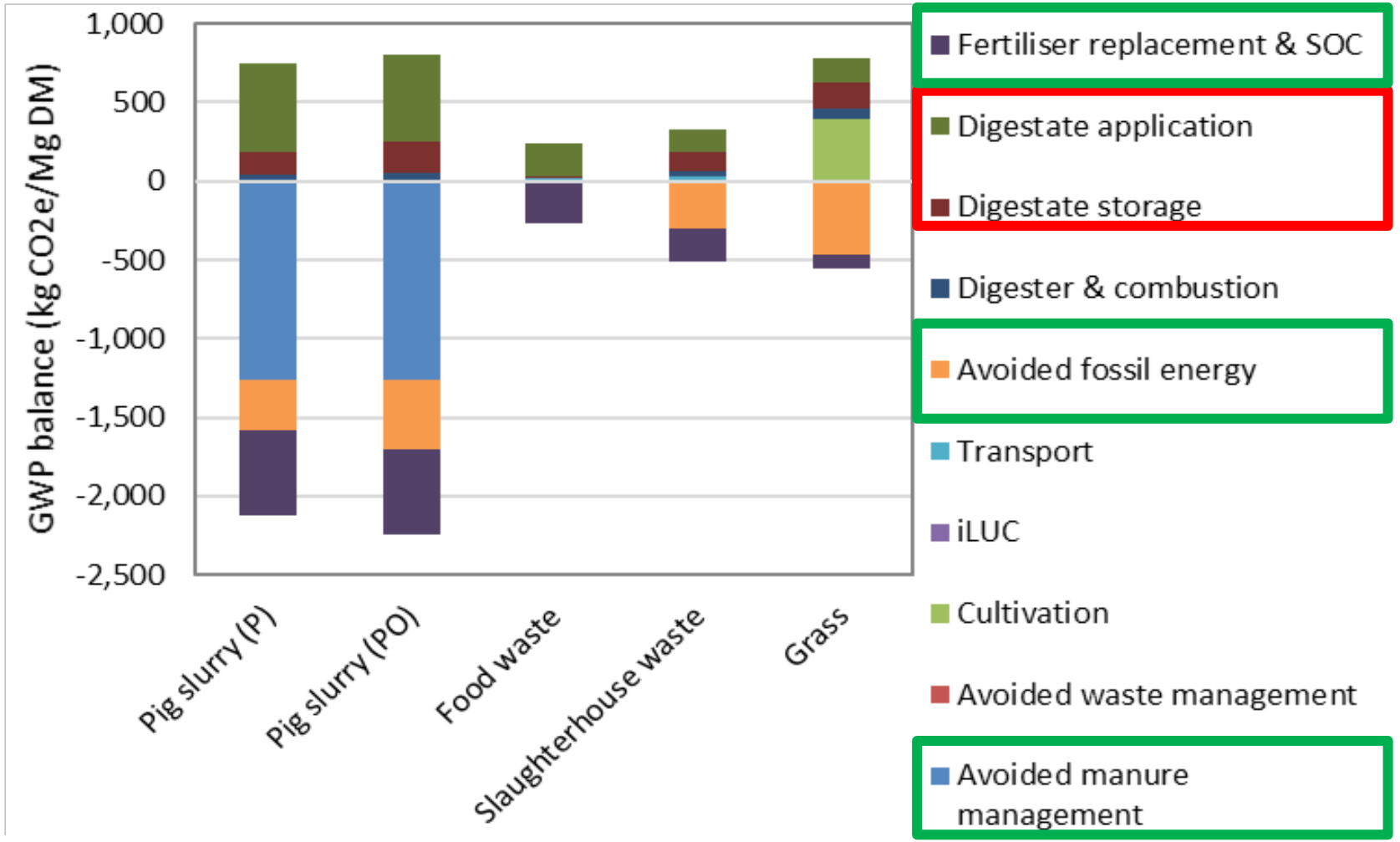
- Two farm biogas typologies in Southern Sweden (Ahlberg-Eliasson et al., 2017)

Substrate/parameter		Pig slurry (P)	Pig slurry & organic residues (PO)*
Pig slurry	Substrate Loading Rate (Mg FM yr^{-1})	10,052	10,927
Food waste		0	535
Slaughterhouse waste		0	1,042
Grass silage		0	185
Biomethane yield	m^3 Mg^{-1} FM	10 (±3.3 SEM)	18 (±3.3 SEM)
***Composition derived from approximate average % VS contributions across 9 plants of 65% pig slurry, 15% food waste, 15% slaughterhouse waste, and 5% grass silage (Ahlberg-Eliasson et al., 2017)**			

- Substrate characteristics

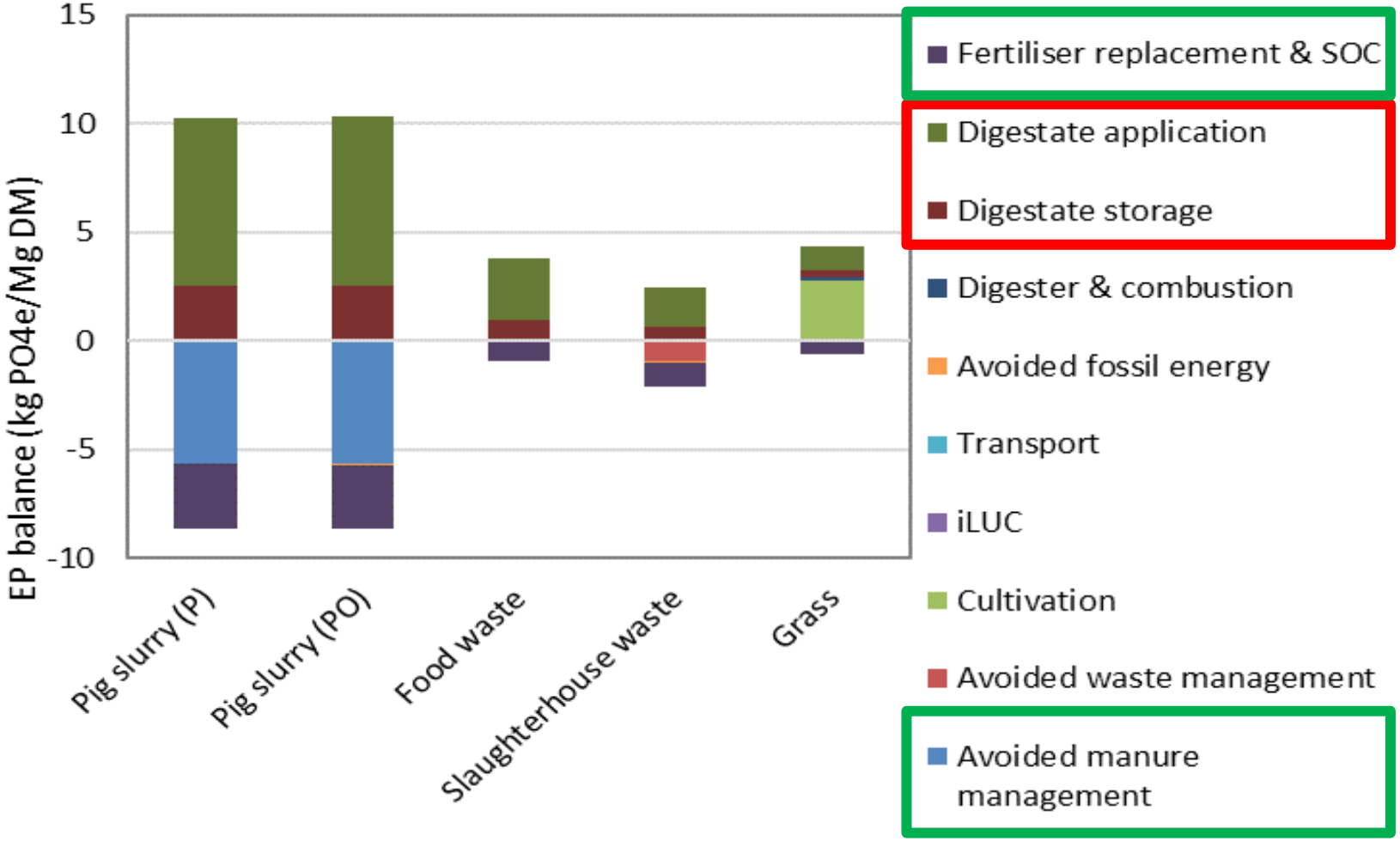
Substrate	Total solids	Volatile solids	N_{org}	NH_4-N	N_{tot}	P	K
	kg Mg^{-1} FM						
Pig slurry	62	49.6	1.83	2.63	4.47	0.77	2.0
Food waste	260	234	1.40	5.62	7.02	0.57	2.74
Slaughterhouse waste	150	120	1.25	1.81	3.06	1.53	1.57
Grass silage	250	225	3.39	1.99	5.38	0.87	5.19
(Ahlberg-Eliasson et al., 2017)(FNR, 2012) (Styles et al., 2016)							

Results: Environmental dimension
Global Warming Potential



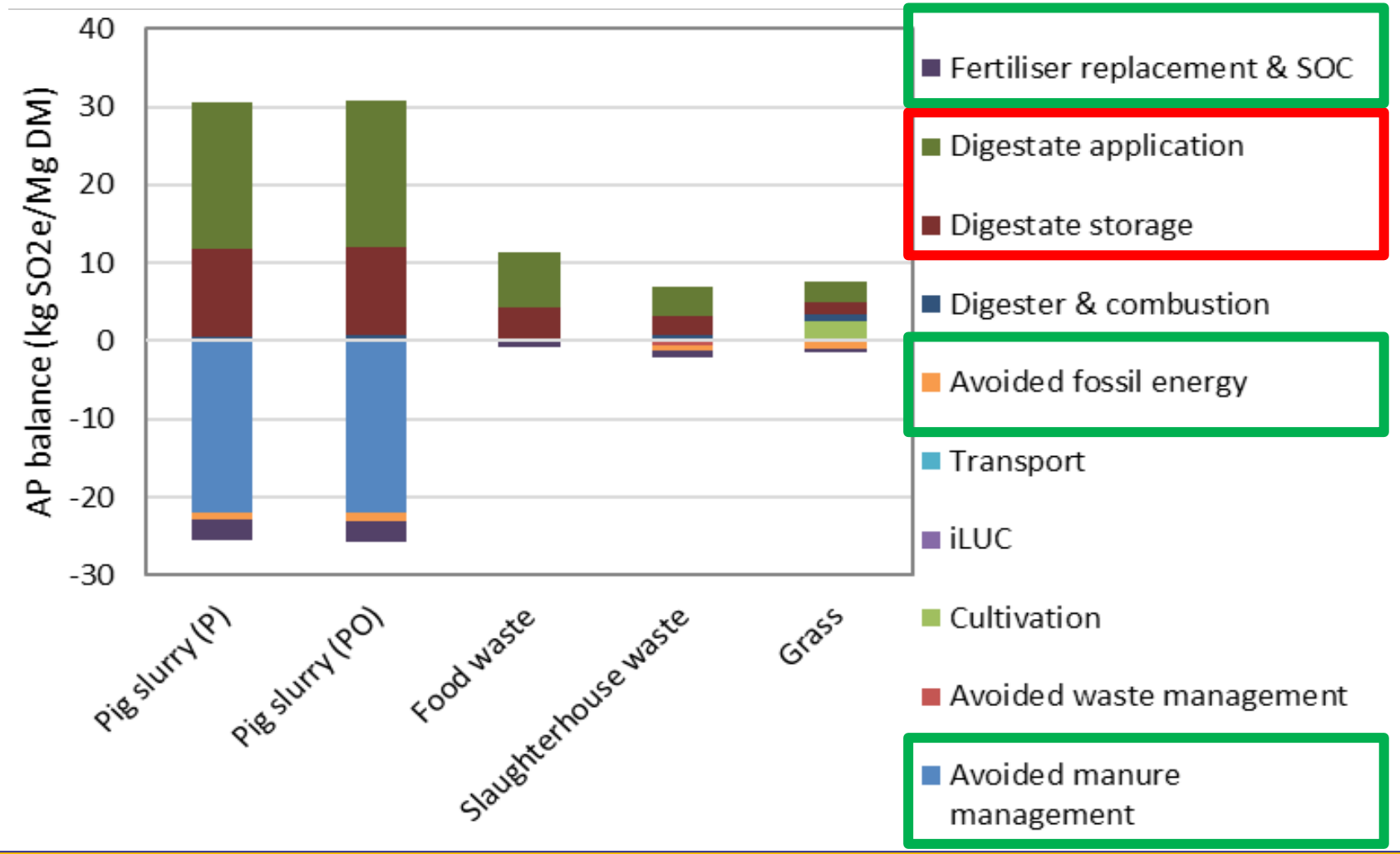
⇒ Global warming potential significantly reduces through pig slurry digestion
⇒ Main impacting factor: avoidance of conventional manure management (slurry storage + spreading)

Results: Environmental dimension
Eutrophication Potential



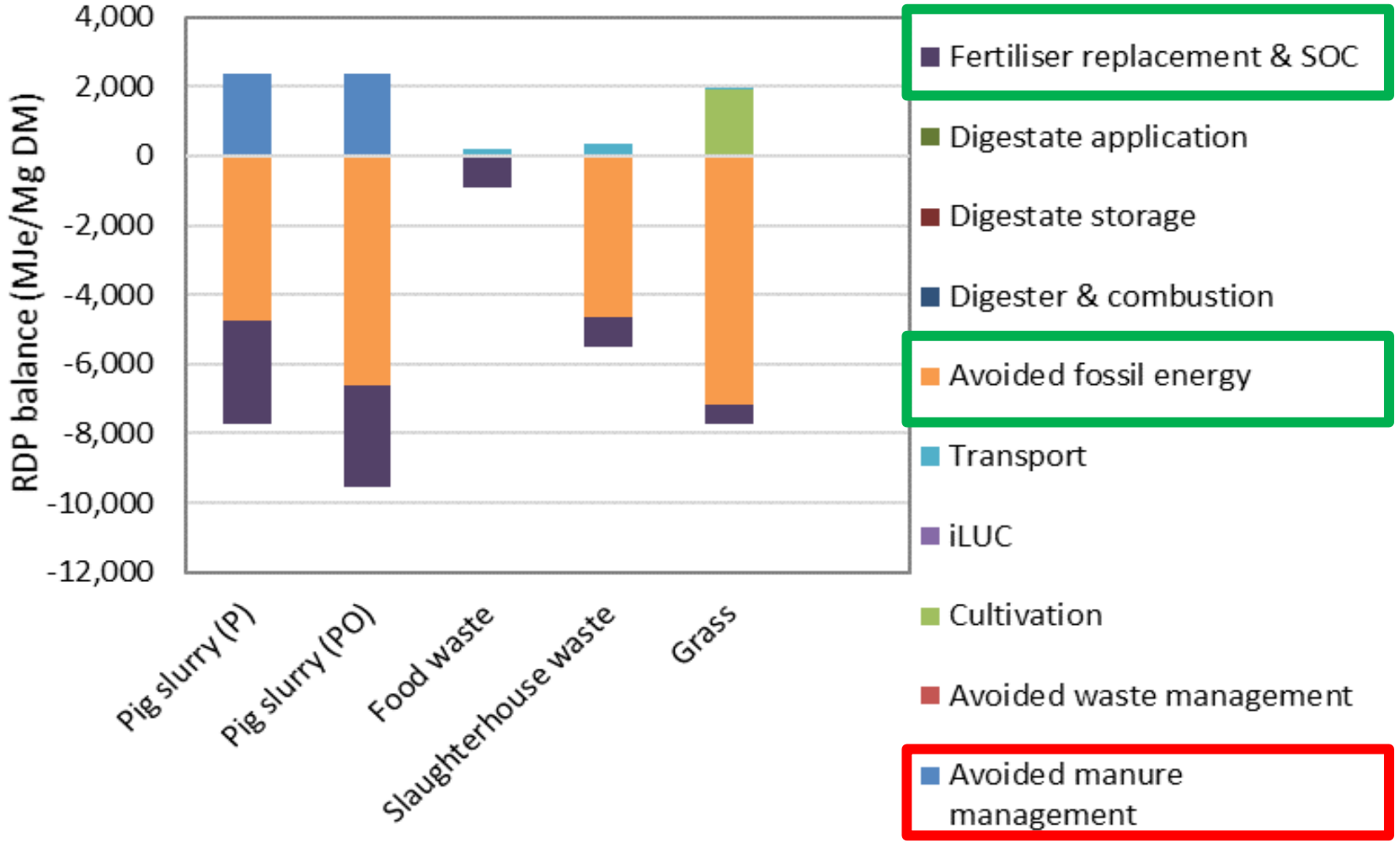
⇒ Eutrophication potential slightly increases through pig slurry digestion
⇒ Main impacting factors: ammonia emissions from digestate storage and application vs. counterfactual emissions from undigested pig slurry storage and application

Results: Environmental dimension
Acidification Potential



⇒ Acidification potential slightly increases through pig slurry digestion
⇒ Main impacting factors: ammonia emissions from digestate storage and application vs. counterfactual emissions from undigested pig slurry storage and application

Results: Environmental dimension
Fossil Resource Depletion Potential



⇒ Fossil resource depletion potential significantly reduces through digestion

⇒ Main impacting factors: avoided fossil energy use, fertilizer replacement and soil organic carbon effects vs avoided manure management

Results: Economic and social dimension

- Net present value:
  - Raw liquid digestate handling: -0.5 - 2 euro tonne^{-1} yr^{-1}
  - Solid digestate handling: ~4.5 euro tonne^{-1} yr^{-1} (25 % DW)
  - Main impacting factors: nutrient content, spreading strategy, application rate and time

- Stakeholder perception study:

Key opportunities

- Policy for biofertilizers in place (50%)
- Willingness to use biofertilizers (100%)
- Awareness of and positive opinion on nutrient recycling (100%)

Crucial points of attention

- Quality assurance (100%)
- Technological developments to concentrate mineral nutrients in biofertilizer (100%)
- Transport distance from the biogas plant to the fields (100%)

Conclusions

- The overall environmental balance of farm-scale digestion is positive
  - Slight increase in eutrophication and acidification potential
  - Significant reduction in global warming potential and fossil resource depletion _
  - Adapted digestate storage and application strategies can improve the overall balance

- The net present value of digestate handling at farm-scale can be positive
  - Main impacting factors: nutrient content, spreading strategy, application rate and time

- Stakeholder perception on the use of recycled products in agriculture is positive
  - Key issue = quality assurance!

- Key barrier for multi-dimensional sustainability assessment
  = wide variation of feedstock characteristics and environmental conditions (e.g., temperature, soil texture) over space and time!

Current work

- Development of a spatiotemporal and multi-dimensional decision-support tool for organic waste valorization

Further reading

Resources, Conservation & Recycling 136 (2018) 110–117

Contents lists available at ScienceDirect

Resources, Conservation & Recycling

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

Full length article

Closing nutrient loops through decentralized anaerobic digestion of organic residues in agricultural regions: A multi-dimensional sustainability assessment

Céline Vaneeckhaute[a,b,*], David Styles[c], Thomas Prade[d], Paul Adams[e], Gunnar Thelin[f], Lena Rodhe[g], Inga Gunnarsson[h], Tina D'Hertefeldt[h]

[a] BioEngine, Chemical Engineering Department, Université Laval, 1065 avenue de la Médecine, Québec, QC, G1V 0A6, Canada
[b] CentrEau, Centre de recherche sur l'eau, Université Laval, 1065 avenue de la Médecine, Québec, QC, G1V 0A6, Canada
[c] School of Environment, Natural Resources and Geography, Bangor University, Gwynedd, LL57 2UW, UK and Plant & AgriBioSciences Centre, Ryan Institute, NUI Galway, Galway, Ireland
[d] Department of Biosystems and Technology, Swedish University of Agricultural Sciences, Alnarp, SE-23053, Sweden
[e] Department of Mechanical Engineering, Bath University, North East Somerset, BA2 7AY, UK
[f] Ekobalans, Scheelevägen 22, Lund, SE-22363, Sweden
[g] RISE Research Institutes of Sweden, Uppsala, SE-75007, Sweden
[h] Department of Biology, Lund University, Lund, SE-22362, Sweden

ARTICLE INFO

Keywords:
Anaerobic digestion
Bio-based fertilizers
Circular economy
Resource recovery
Sustainable farming
Nutrient management

ABSTRACT

Decentralized anaerobic digestion (AD) of manure and organic residues is a possible strategy to improve carbon and nutrient cycling within agricultural regions, meanwhile generating renewable energy. To date, there has been limited adoption of decentralized AD technology in industrialized countries owing to low profitability for plant operators. There remains a need to demonstrate the wider sustainability of small-scale, decentralized AD in order to justify policy support for such a strategy. This study applies a multi-dimensional assessment of the environmental, economic and social sustainability of two scenarios of decentralized, farm-scale AD of pig slurry and organic residues in Southern Sweden. The environmental dimension was assessed by means of an expanded boundary life cycle assessment, in which trade-offs between fertilizer replacement, soil organic carbon accumulation, digestate/manure storage and application, transport and soil emissions were evaluated. The economic dimension was assessed through modelling of the net present value and internal rate of return. Finally, the social dimension was assessed by means of a stakeholder perception inquiry among key stakeholders in the field. It was concluded that the overall environmental balance of decentralized AD was favorable, while also the net present value could be positive. Fertilizer replacement, soil organic carbon and digestate storage effects were identified as important factors that should be accounted for in future life cycle assessments. A key issue for interviewed stakeholders was product quality assurance. Wider application of multi-dimensional sustainability assessment, capturing important nutrient cycling effects, could provide an evidence base for policy to support sustainable deployment of decentralized AD.

References

- Ahlberg-Eliassen et al. (2017) Production efficiency of Swedish farm-scale biogas plants. Biomass and Bioenergy, 97, 27–37.
- Andersons (2013) NNFCC AD Calculator (confidential).
- EUBIA (2017) Anaerobic Digestion. Report, European Biomass Industry Association, available from: http://www.eubia.org/cms/wiki-biomass/anaerobic-digestion/
- Eurostat (2017) Greenhouse gas emission statistics. European Commission, available from: http://ec.europa.eu/eurostat/statistics-explained/index.php/Greenhouse_gas_emission_statistics
- FNR (2012). Guide to Biogas: From production to use. Fachagentur Nachwachsende Rohstoffe e. V. (FNR), Gulzow, Germany, available from: https://mediathek.fnr.de/media/downloadable/files/samples/g/u/guide_biogas_engl_2012.pdf
- Rodhe et al. (2006) Handling of digestate on farm level. JTI-report Agriculture & Industy no. 347, Swedish Institute of Agricultural and Environmental Engineering, Sweden.
- Styles et al. (2016) Environmental balance of the UK biogas sector: An evaluation by consequential life cycle assessment. Science of the Total Environment, 560–561.

Questions ?

celine.vaneeckhaute@gch.ulaval.ca
https://bioengineblog.wordpress.com

BioEngine

UNIVERSITÉ LAVAL

NSERC CRSNG