RCN Conference on
Pan American Biofuels
& Bioenergy Sustainability
Golden Tulip Recife Palace,
Recife, Brazil July 22-25, 2014

PAN-AMERICAN BIOFUELS & BIOENERGY SUSTAINABILITY
AN NSF RESEARCH COORDINATION NETWORK

NEST Experience in Life Cycle Assessment (LCA) Research and Development Projects Related with Biofuels and Residues Energy Conversion

MSc. Mateus Henrique Rocha
Prof. Dr. Electo Eduardo Silva Lora
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Universidade Federal de Itajubá

NEST

Excellence Group in Thermal and Distributed Generation

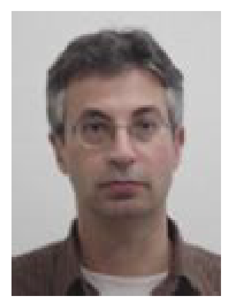
Mechanical Engineering Institute

EXCELLENCE GROUP IN THERMAL POWER AND DISTRIBUTED GENERATION - NEST

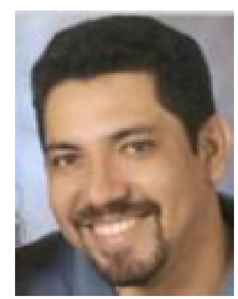
Professor
Dr. Electo S. Lora

Professor
Dr. Osvaldo J. Venturini

Professor
Dr. Vladimir M. Cobas



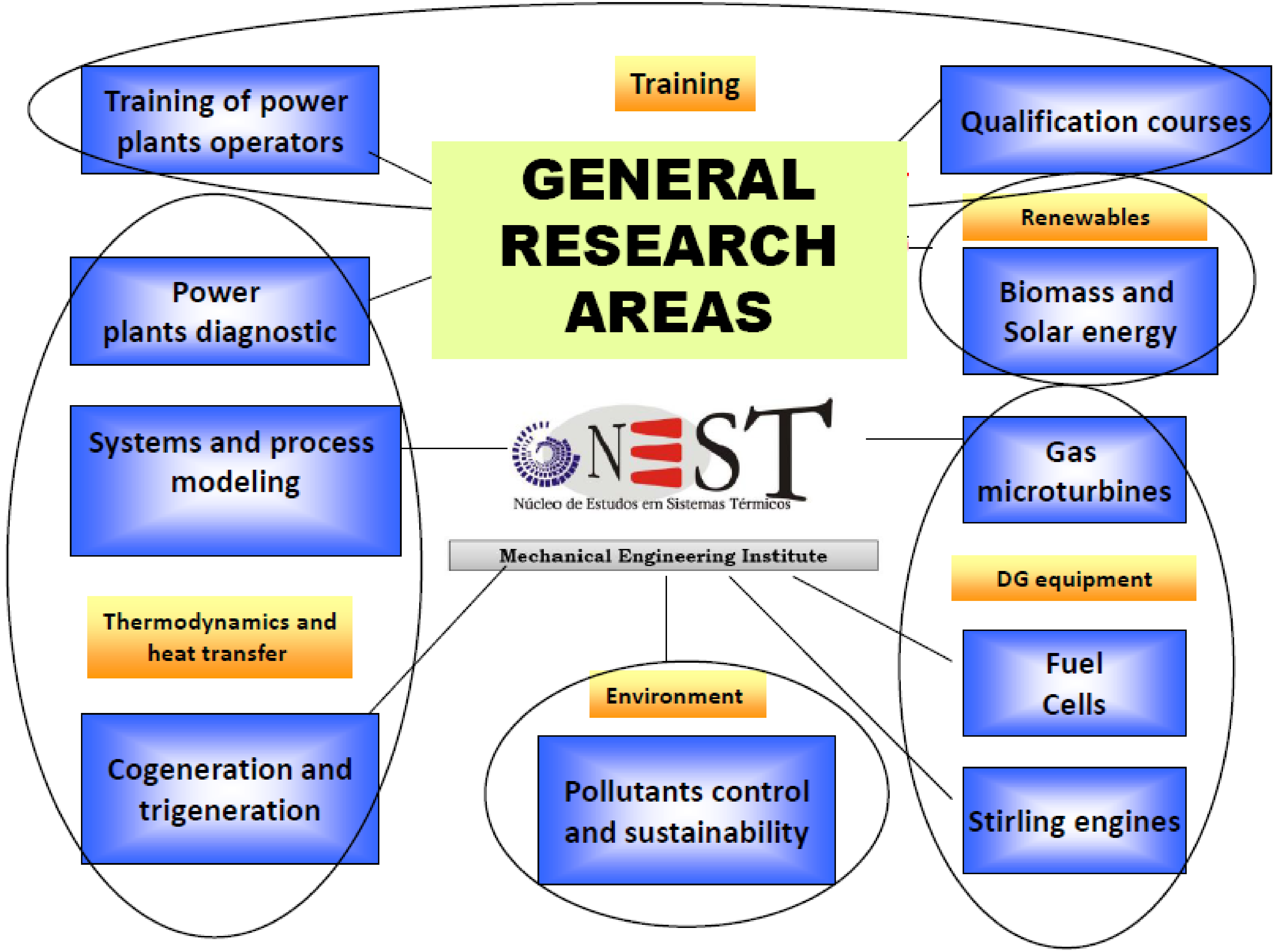
Professor
Dr. Ricardo D. M. Carvalho



Professor
Dr Rubenildo Vieira Andrade

Professor
DrJosé Carlos Escobar Palacio

++++ PhD and Master degree students



GENERAL RESEARCH AREAS
Training
Training of power plants operators
Qualification courses
Renewables
Biomass and Solar energy
Power plants diagnostic
Systems and process modeling
NEST
Núcleo de Estudos em Sistemas Térmicos
Mechanical Engineering Institute
Gas microturbines
DG equipment
Fuel Cells
Stirling engines
Thermodynamics and heat transfer
Cogeneration and trigeneration
Environment
Pollutants control and sustainability


LCA and Biofuels Sustainability
Biomass Gasification
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Solid Oxide Fuel Cell
FUEL CELL
Microturbines and Chillers
Cogeneration system
Stirling Engine

Our laboratories

Bubbling bed gasifier

Gas microturbines and chiller

Steam cycle

Refrigeration and air conditioning

Solo Stirling engine

Traning center for power plants operators

ETC…..






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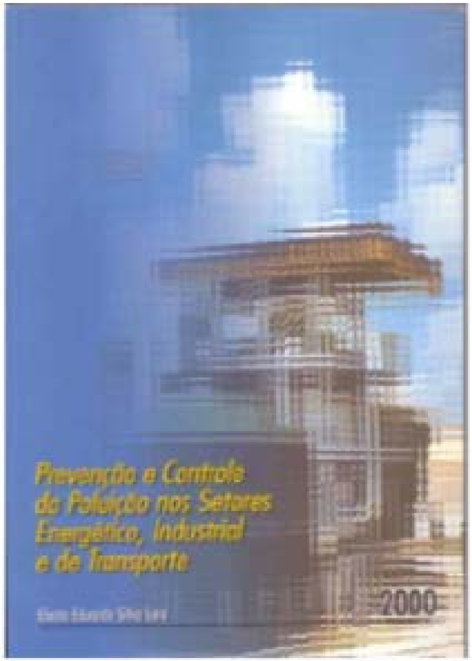
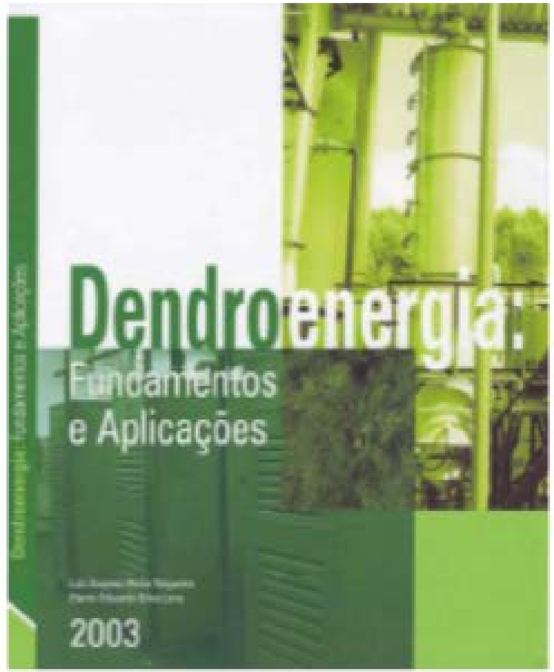
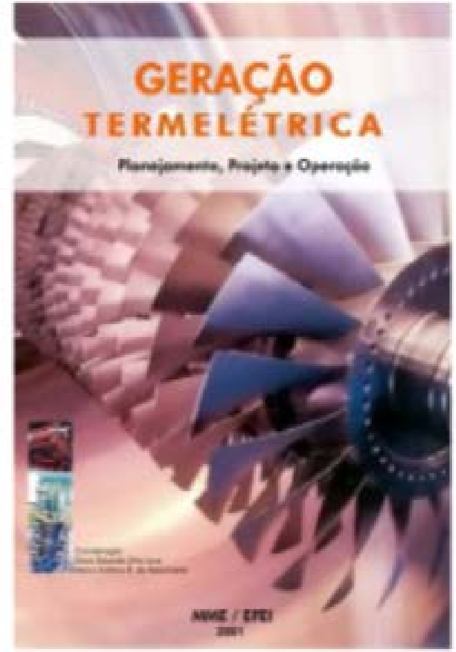
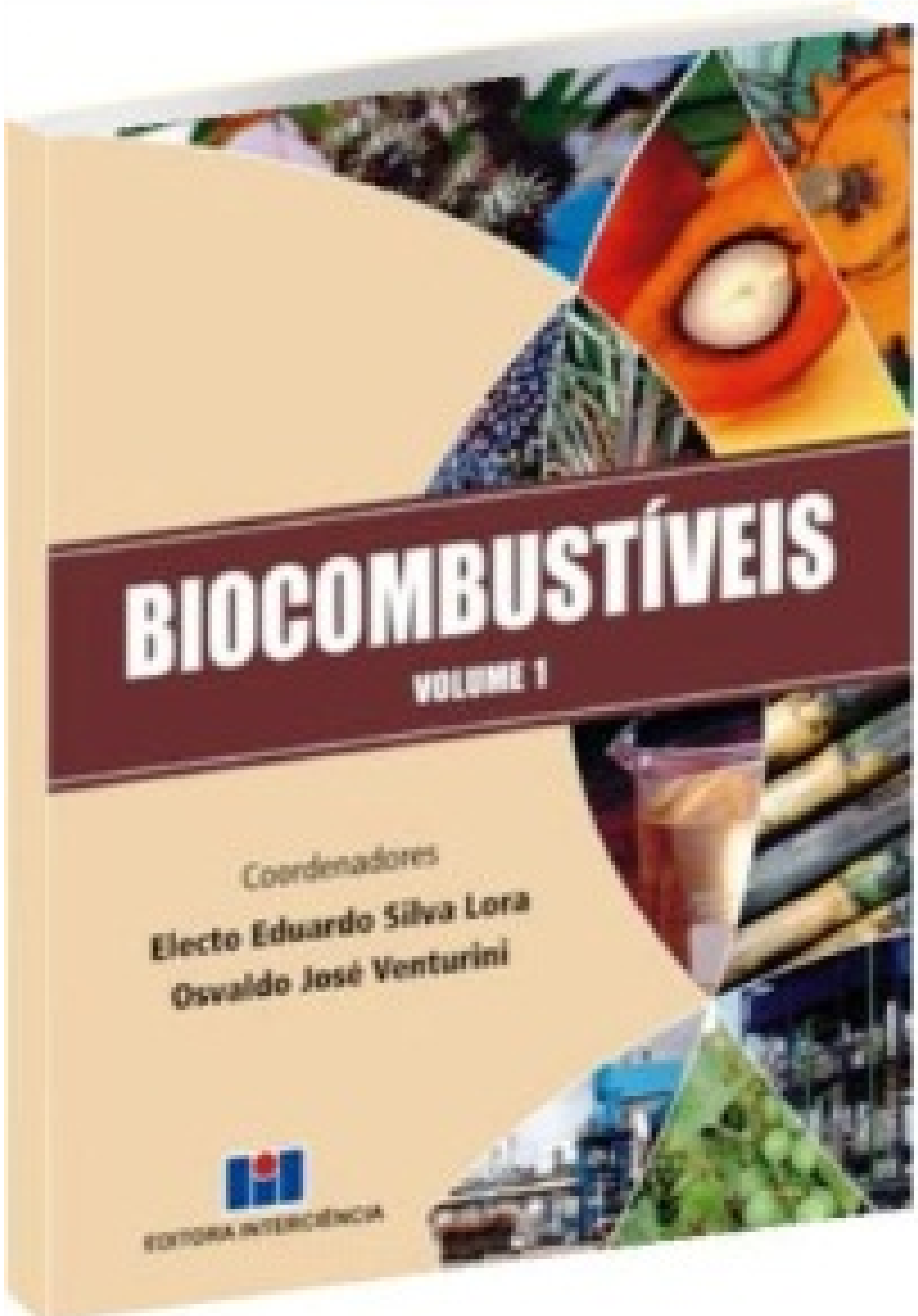






PUBLISHED BOOKS AT NEST/UNIFEI



Chapter 1 – Biofuels: fundamentals

Chapter 2 – Combustion of Biomass

Chapter 3 – Biodiesel

Chapter 4 – Biogas

Chapter 5 – First Generation Bioethanol

Chapter 6 – Pyrolysis and Gasification of Biomass

Chapter 7 – Biomass to Liquid

Chapter 8 – Lignocellulosic Bioethanol

Chapter 9 – Utilization of $BioH_2$ in Fuel Cells

Chapter 10 – Utilization of Biofuels in IC Engines

Chapter 11 – Utilization of Biofuels in Microturbines

Chapter 12 – Residues Stillage and Glycerin

Chapter 13 – Cogeneration in Biofuels Production

Chapter 14 – Planning and Projects Management in Biofuels

Chapter 15 – Environmental Integrated Evaluation

Chapter 16 – The future of Biofuels: Biorefineries, Biodiesel from Algae and Microbial Fuel Cells

New installations: Office and Laboratories

Funding
ANP/PETROBRAS
R$ 4.151.430,00

To be completed in 2015




NEST Experience in Research and Development Projects Related With Biomass Energy Conversion

Main NEST Published Papers in Biomass Energy Conversion

BIOMASS AND BIOENERGY 61 (2014) 236–244

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Available online at www.sciencedirect.com

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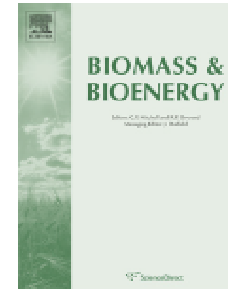

Biomass gasification in a downdraft gasifier with a two-stage air supply: Effect of operating conditions on gas quality

CrossMark

Ana Lisbeth Galindo [a], *Electo Silva Lora* [a,*], *Rubenildo Viera Andrade* [a], *Sandra Yamile Giraldo* [a], *Rene Lesme Jaén* [b], *Vladimir Melian Cobas* [a]

[a] *Excellence Group in Thermal Power and Distributed Generation-NEST, Institute of Mechanical Engineering, Federal University of Itajubá, Brazil*

[b] *Faculty of Mechanical Engineering, Center for Energy Efficiency Studies, University of Oriente, Cuba*

Evaluation of the quality of the producer gas in a two-stage, air supply downdraft gasifier. The gas composition and its lower heating value were also determined. Experimental tests were performed varying the operating conditions of the gasifier: the air flow between 18 Nm^3/h and 22 Nm^3/h. The results show that a fuel gas, with tar and particulate matter content of 54.25±0.66 mg/Nm^3 and 102.4±1.09 mg/Nm^3, respectively, was obtained, for a total air flow rate of 20±0.45 Nm^3/h and an air ratio, between the two stages, of 80%. For these conditions, the lower heating value of the gas was 4.74±0.5 MJ/Nm^3.

Main NEST Published Papers in Biomass Energy Conversion

Renewable Energy 60 (2013) 427–432

Contents lists available at SciVerse ScienceDirect

Renewable Energy

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

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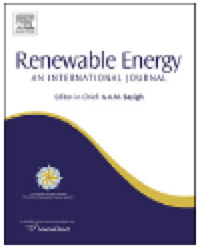


Prediction by mathematical modeling of the behavior of an internal combustion engine to be fed with gas from biomass, in comparison to the same engine fueled with gasoline or methane

CrossMark

Felipe O. Centeno González [a,*], Khamid Mahkamov [b], Electo E. Silva Lora [a], Rubenildo V. Andrade [a], René Lesme Jaen [c]

[a] *The Centre for Excellency in Thermoelectric and Distributed Generation (NEST), The Federal University of Itajuba, Av. BPS 1303 Pinheirinho, Itajuba, MG, Brazil*
[b] *School of Computing, Engineering and Information Sciences, Northumbria University, Ellison Building, Newcastle upon Tyne NE1 8ST, UK*
[c] *University of Oriente, Sede J.A. Mella. Ave. de las Américas s/n y calle I. C.P. 90900 Santiago de Cuba, Cuba*

The performance of a spark ignition internal combustion engine fueled with synthesis gas (syngas) from biomass gasification was evaluated using an analytical mathematical model. The model predicted of the internal temperatures profiles, heat flow, as well as the work and pressure in relation to crank angle. It was used also to evaluate the influence of the rotation speed, the air ratio and the ignition timing on the engine indicated power. It was found that when feeding the engine with syngas, a power output between 59 and 65% could be obtained, in comparison it's powered by gasoline.

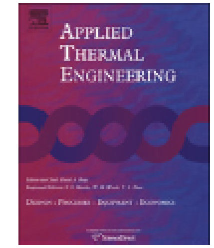
Main NEST Published Papers in Biomass Energy Conversion

Applied Thermal Engineering 52 (2013) 109–119

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

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



Exergetic and economic comparison of ORC and Kalina cycle for low temperature enhanced geothermal system in Brazil

Carlos Eymel Campos Rodríguez [a,*], José Carlos Escobar Palacio [a], Osvaldo J. Venturini [a], Electo E. Silva Lora [a], Vladimir Melián Cobas [a], Daniel Marques dos Santos [b], Fábio R. Lofrano Dotto [c], Vernei Gialluca [d]

[a] Federal University of Itajuba (UNIFEI), Mechanical Engineering Institute – IEM, Excellence Group in Thermal Power and Distributed Generation (NEST), Minas Gerais, Brazil
[b] AES Tietê, Bauru, São Paulo, Brazil
[c] FAROL Pesquisa, Desenvolvimento e Consultoria, Brazil
[d] Gênera Serviços e Comércio LTDA, Brazil

Thermodynamic analysis, of both the first and second law of thermodynamic of two different technologies (ORC and Kalina cycle) for power production through an enhanced geothermal system. In order to find a better performance of both thermal cycles it were evaluated 15 different working fluids for ORC and three different composition of the ammonia-water mixture for the Kalina cycle. At the end the two cycles was compared using an economic analysis with the fluid that offers the best performance for each thermal cycle which are R-290 for ORC and for Kalina cycle a composition of the mixture of 84% of ammonia mass fraction and 16% of water mass fraction.

Main NEST Published Papers in Biomass Energy Conversion

BIOMASS AND BIOENERGY 58 (2013) 76–86

ELSEVIER

Available online at www.sciencedirect.com

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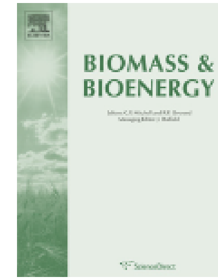

Assaí – An energy view on an Amazon residue

CrossMark

Marcos Alexandre Teixeira [c,*,2], José Carlos Escobar Palacio [b], César Rodriguez Sotomonte [b], Electo Eduardo Silva Lora [b], Osvaldo José Venturini [b], Dirk Aßmann [a,1]

[a] GIZ – Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH, Energy Program, Brazil. c/o Edifício Rodolpho de Paoli, Av. Nilo Peçanha, 50 - 30° andar, grupo 3009, Centro - Rio de Janeiro, RJ 20020-906, Brazil

[b] Núcleo de Excelência em Geração Termelétrica e Distribuida – NEST, Instituto de Engenharia Mecânica – IEM, Universidade Federal de Itajubá – UNIFEI, Av. BS 1303, CP 50, Itajubá, MG 97500-093, Brazil

[c] Federal Fluminense University, Department of Agricultural Engineering and the Environment, Rua Passo da Pátria 156, CEP 24.210-240 Niterói, RJ, Brazil

The paper analyzed the economic feasibility of electricity generation using the residues from the exploitation of Assaí. The electricity generation cost for a 1 MW conversion systems, considering 5.5 US$/ton biomass price, were evaluated: conventional steam cycle with backpressure turbine (66.97 US$/MWh), steam cycle with extraction condensation turbine (92.11 US$/MWh), Organic Rankine cycle (122 US$/MWh) and a gasifier/ICE set (102 US$/MWh). Based on financial performance, backpressure steam turbine was the best option, and gasifier/ICE should be further considered due its operation flexibility. For any system, minimal electricity commercialization price for economical feasibility found was 150 US$/MWh.

Main NEST Published Papers in Biomass Energy Conversion

Renewable Energy 37 (2012) 97–108

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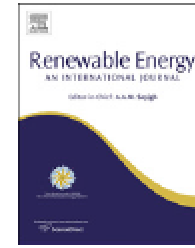
Contents lists available at ScienceDirect

Renewable Energy

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



Theoretical and experimental investigations of a downdraft biomass gasifier-spark ignition engine power system

Felipe Centeno [a], Khamid Mahkamov [b], Electo E. Silva Lora [a,*], Rubenildo V. Andrade [a]

[a] The Centre for Excellency in Thermoelectric and Distributed Generation (NEST), The Federal University of Itajuba, Av. BPS 1303 Pinheirinho, Itajuba, MG, Brazil
[b] School of Computing, Engineering and Information Sciences, Northumbria University, Ellison Building, Newcastle upon Tyne NE1 8ST, UK

A mathematical model was developed to predict steady state performance of a biomass downdraft gasifier/spark ignition engine power system. A mathematical model of the integrated system consists of two parts: the fixed bed downdraft gasifier and spark ignition internal combustion engine models. The numerical results obtained using the proposed model are in a good agreement with data produced with the use of other theoretical models and experimental data published in literature. The proposed model is applicable for modelling integrated downdraft gasifier/engine biomass energy systems and can be used for more accurate adjustment of design parameters of the gasifier and the engine in order to provide the higher overall efficiency of the system.

Main NEST Published Papers in Biomass Energy Conversion

BIOMASS AND BIOENERGY 35 (2011) 3465–3480

ELSEVIER

Available at www.sciencedirect.com

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BIOMASS & BIOENERGY

Experimental study on biomass gasification in a double air stage downdraft reactor

Juan Daniel Martínez [a,b,*], *Electo Eduardo Silva Lora* [a,**], *Rubenildo Viera Andrade* [a], *René Lesme Jaén* [c]

[a] *Núcleo de Excelência em Geração Termelétrica e Distribuída, Instituto de Engenharia Mecânica, Universidade Federal de Itajubá, Av. BPS 1303, Itajubá, Minas Gerais, Brazil*

[b] *Grupo de Investigaciones Ambientales, Instituto de Energía, Materiales y Medio Ambiente, Universidad Pontificia Bolivariana, Circular 1ra N° 70 – 01, Bloque 11, Medellín, Colombia*

[c] *Facultad de Ingeniería Mecánica, Centro de Estudios de Eficiencia Energética, Universidad de Oriente, Av. Las Américas s/n C.P. 90900, Santiago de Cuba, Cuba*

Experimental study of the gasification of a wood biomass in a moving bed downdraft reactor with two-air supply stages. The gasifier produces a combustible gas with a CO, CH_4 and H_2 concentrations of 19.04%, 0.89% and 16.78% volume respectively, at a total flow of air of 20 Nm^3/h and an air between stages of 80%. For these conditions, the LHV of the gas was 4539 kJ/Nm^3. Results from the calculation model show a useful gas power and cold efficiency around 40 kW and 68%, respectively. The resulting ER under the referred operation condition is around 0.40.

Main NEST Published Papers in Biomass Energy Conversion

BIOMASS AND BIOENERGY 33 (2009) 1101–1107

Available at www.sciencedirect.com

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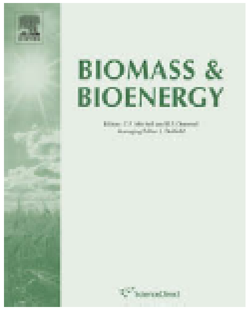

Review

Estimate of the electric energy generating potential for different sources of biogas in Brazil

Karina Ribeiro Salomon, Electo Eduardo Silva Lora*

Federal University of Itajubá – UNIFEI, Excellence Group in Thermal Power and Distributed Generation – NEST/IEM, Av BPS 1303, CP 50, Itajubá, MG, CEP 37.500-903, Brazil

It was carried out an evaluation of the quantities of organic residues coming out from the sugar and alcohol industry (stillage), Municipal Solid Waste (MSW) and liquid wastes (sewage) and livestock residues (bovine and swine manure) in Brazil. Finally the electricity generation potential of biogas out of the evaluated sources of organic residues in Brazil was estimated. The results of this study indicate that the potential regarding the production of biogas out of the aforementioned organic residues of electricity production using could meet an energy demand of about 1.05 to 1.13 %. Constraints for biogas energy utilization was identified and discussed.

NEST Experience in Life Cycle Assessment (LCA) Related With Biofuels

Renewable and Sustainable Energy Reviews 37 (2014) 435–459

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Life cycle assessment (LCA) for biofuels in Brazilian conditions: A meta-analysis

Mateus Henrique Rocha [a,*], Rafael Silva Capaz [b], Electo Eduardo Silva Lora [a], Luiz Augusto Horta Nogueira [b], Marcio Montagnana Vicente Leme [a], Maria Luiza Grillo Renó [a], Oscar Almazán del Olmo [c]

[a] NEST – Excellence Group in Thermal Power and Distributed Generation, Institute of Mechanical Engineering, Federal University of Itajubá, Av. BPS 1303, Itajubá, Minas Gerais State, CEP: 37500-903, Brazil
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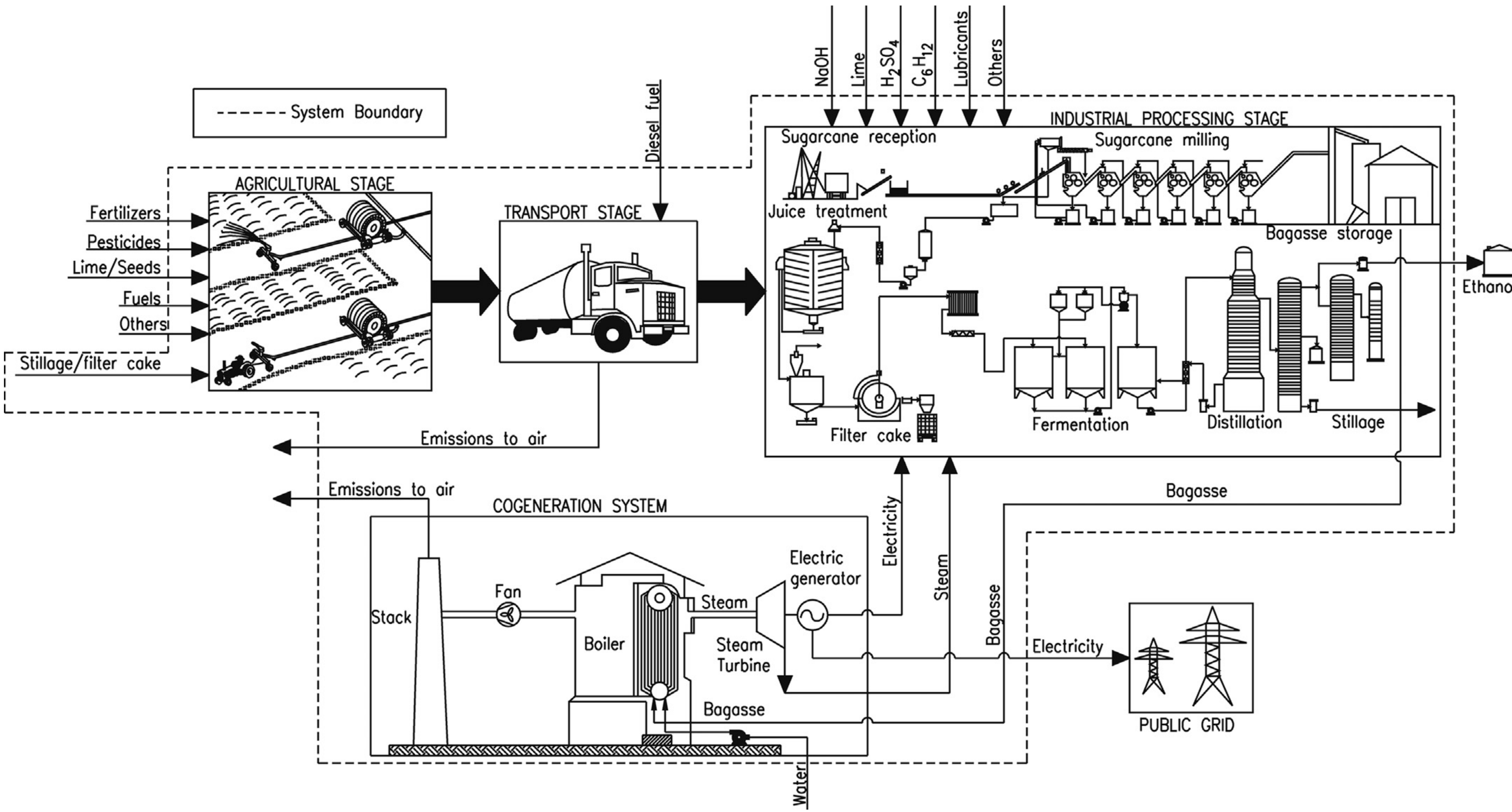
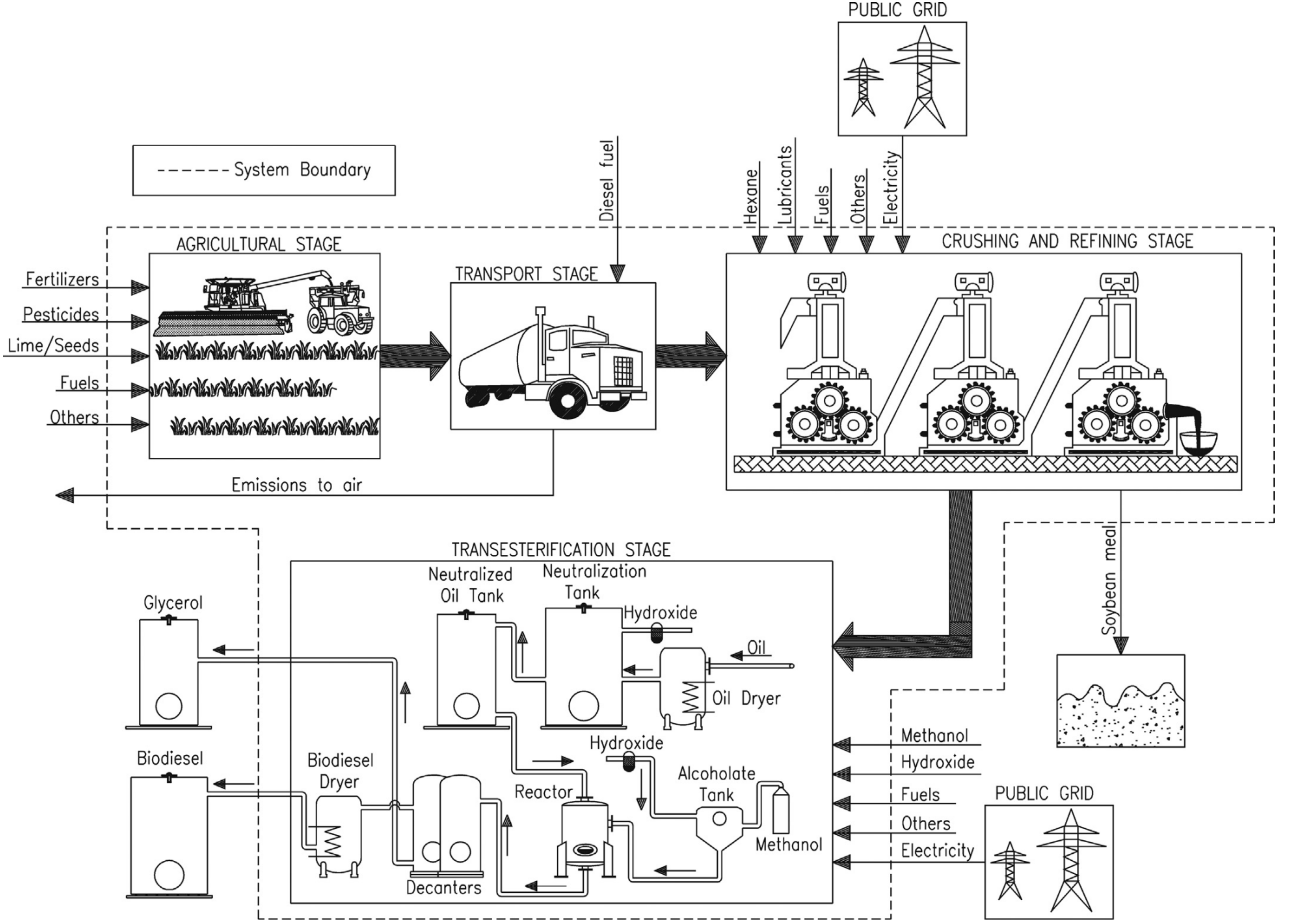
Biofuel	Reference	Country	LCA environmental impacts	LCEA (energy balance)
Ethanol – sugarcane	Capaz [93] – Base case	Brazil	No	Yes
	Macedo et al. [94]	Brazil	GHG emissions	Yes
Biodiesel – Soybean oil	Capaz [43] – Base case	Brazil	No	Yes
	Cavalett and Ortega [95]	Brazil	Emergy Analysis and Embodied Energy Analysis	Yes
	Tsoutsos et al. [96]	Greece	Yes	No
	Pradhan et al. [97]	USA	No	Yes
	Carraretto et al. [98]	Italy	Yes	Yes
Biodiesel – Palm oil	Costa [99] – Base case	Brazil	Yes	Yes
	Kamahara et al. [100]	Indonesia	No	Yes
	Papong et al. [101]	Thailand	No	Yes
	Souza et al. [102]	Brazil	GHG emissions	Yes
	Pleanjai and Gheewala [103]	Thailand	No	Yes

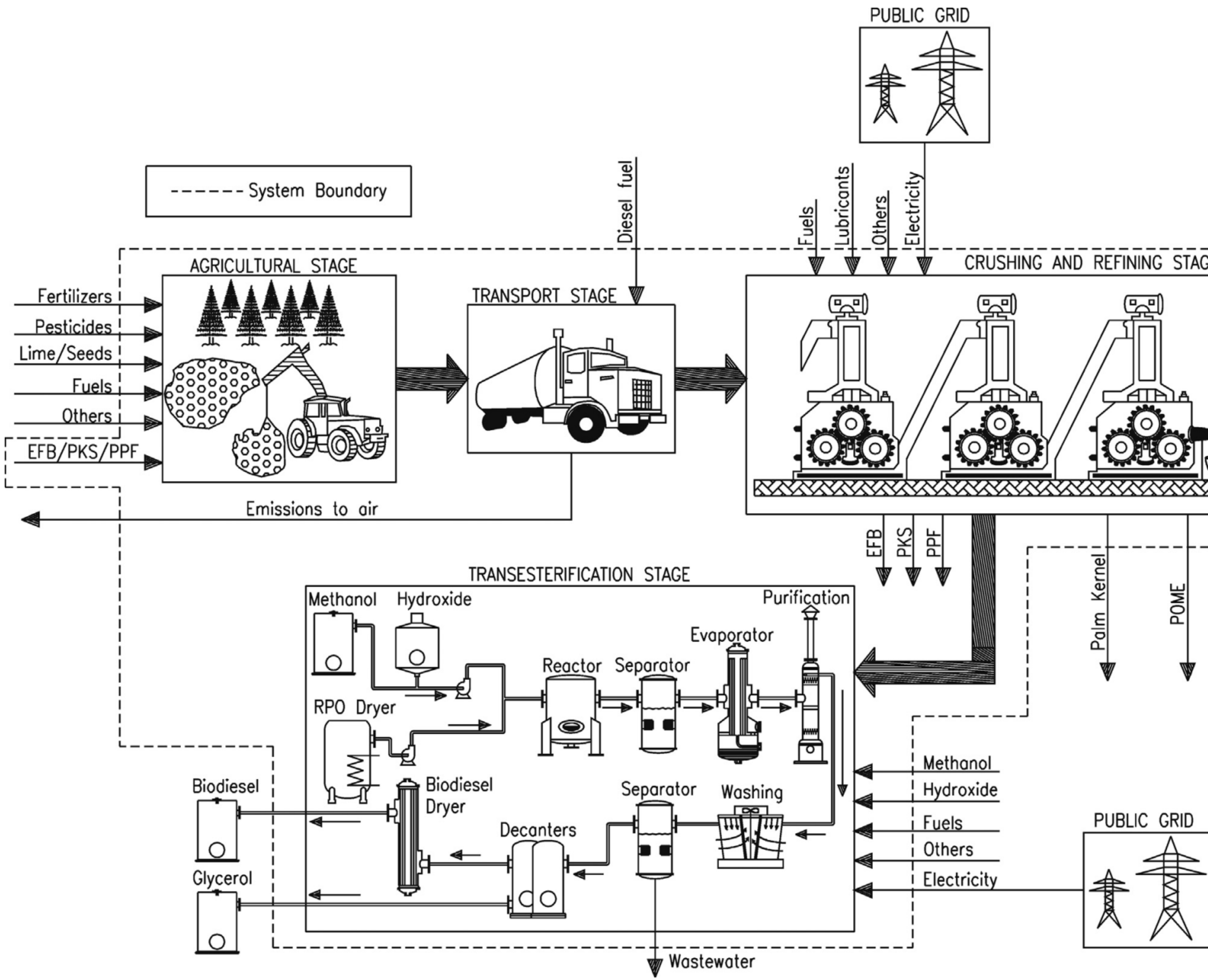
Scheme of the system boundary of the ethanol production from sugarcane.



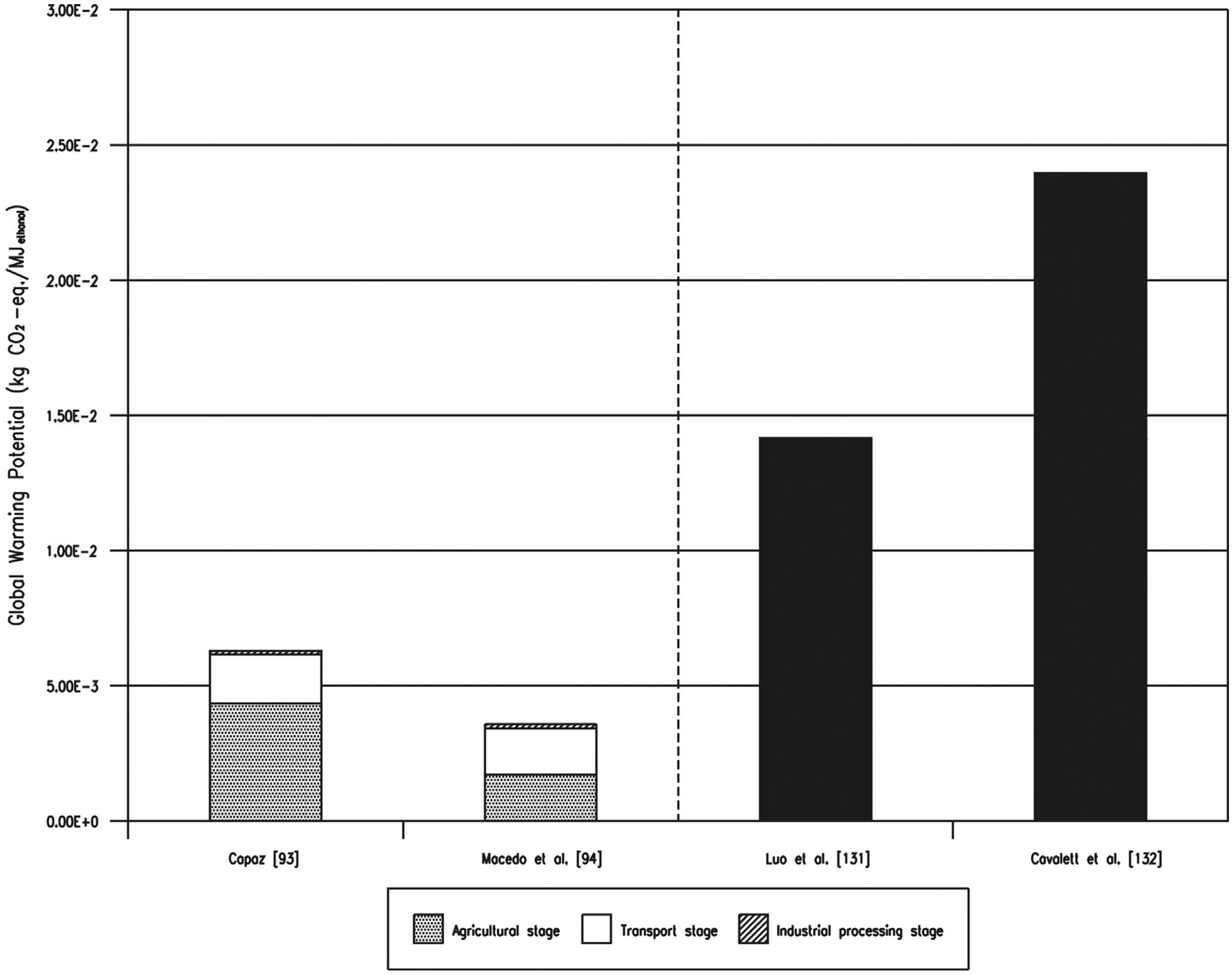
Scheme of the system boundary of the biodiesel production from soybean



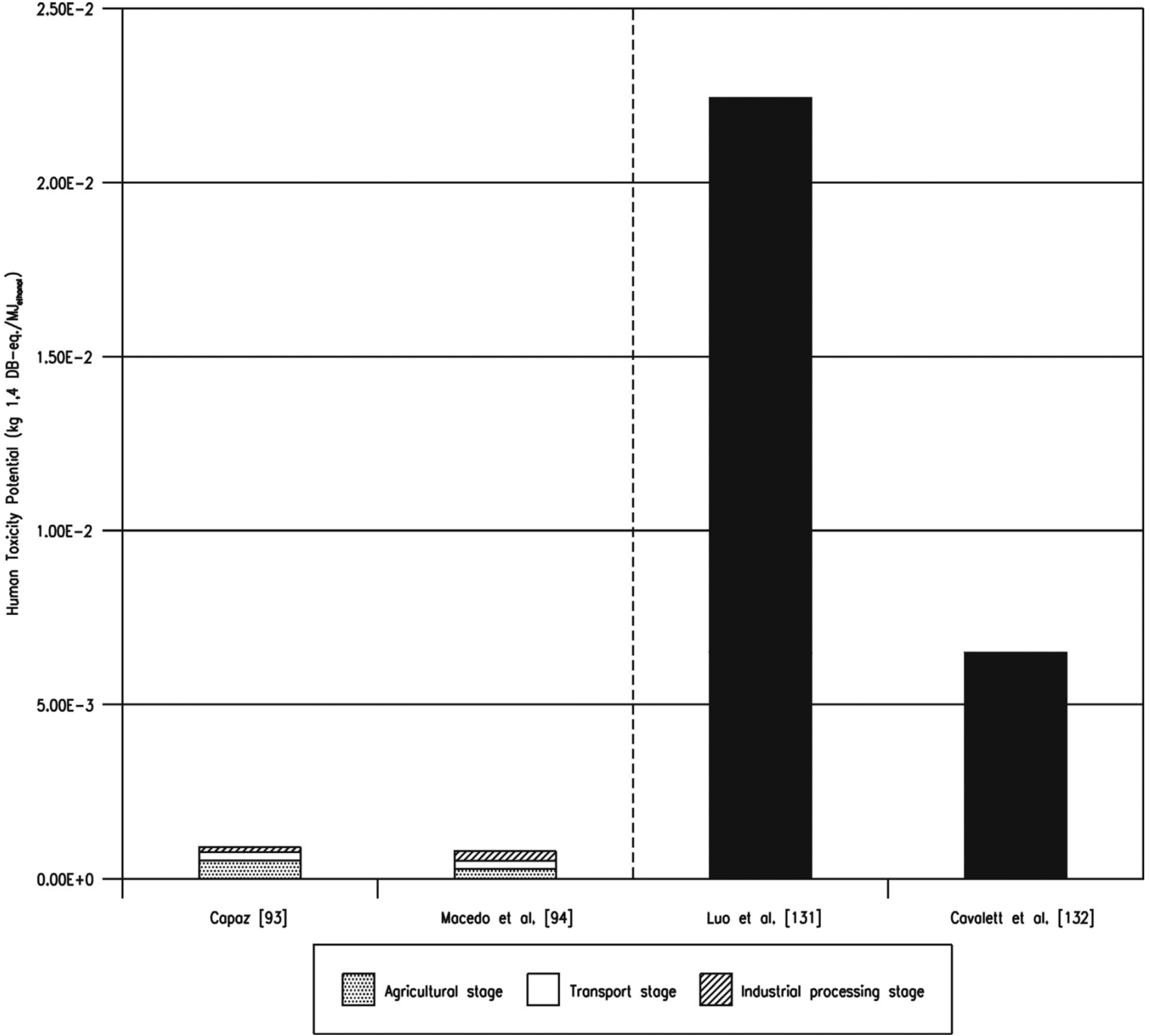
Scheme of the system boundary of the biodiesel production from palm oil



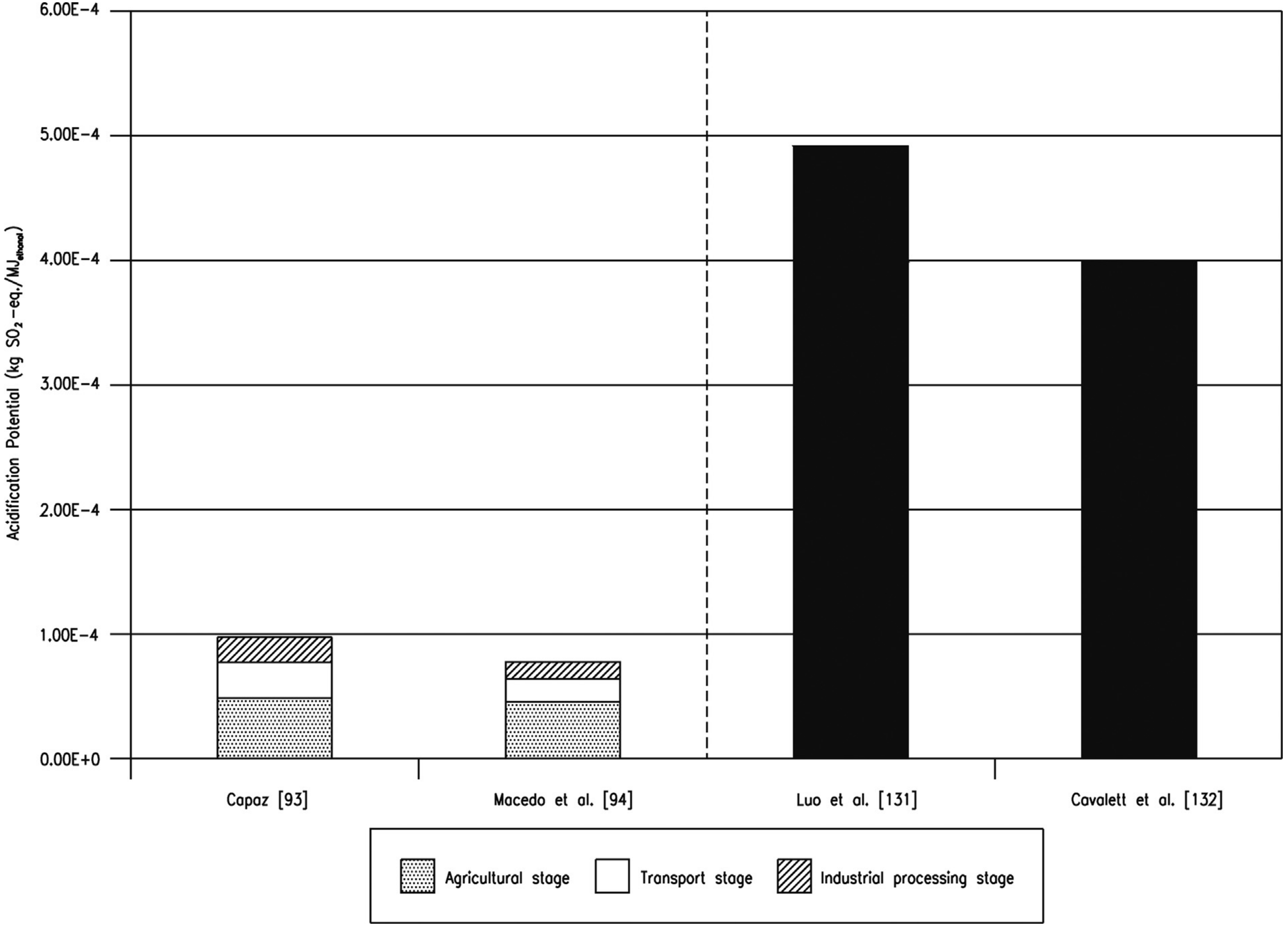
Global Warming Potential in life cycle of ethanol production



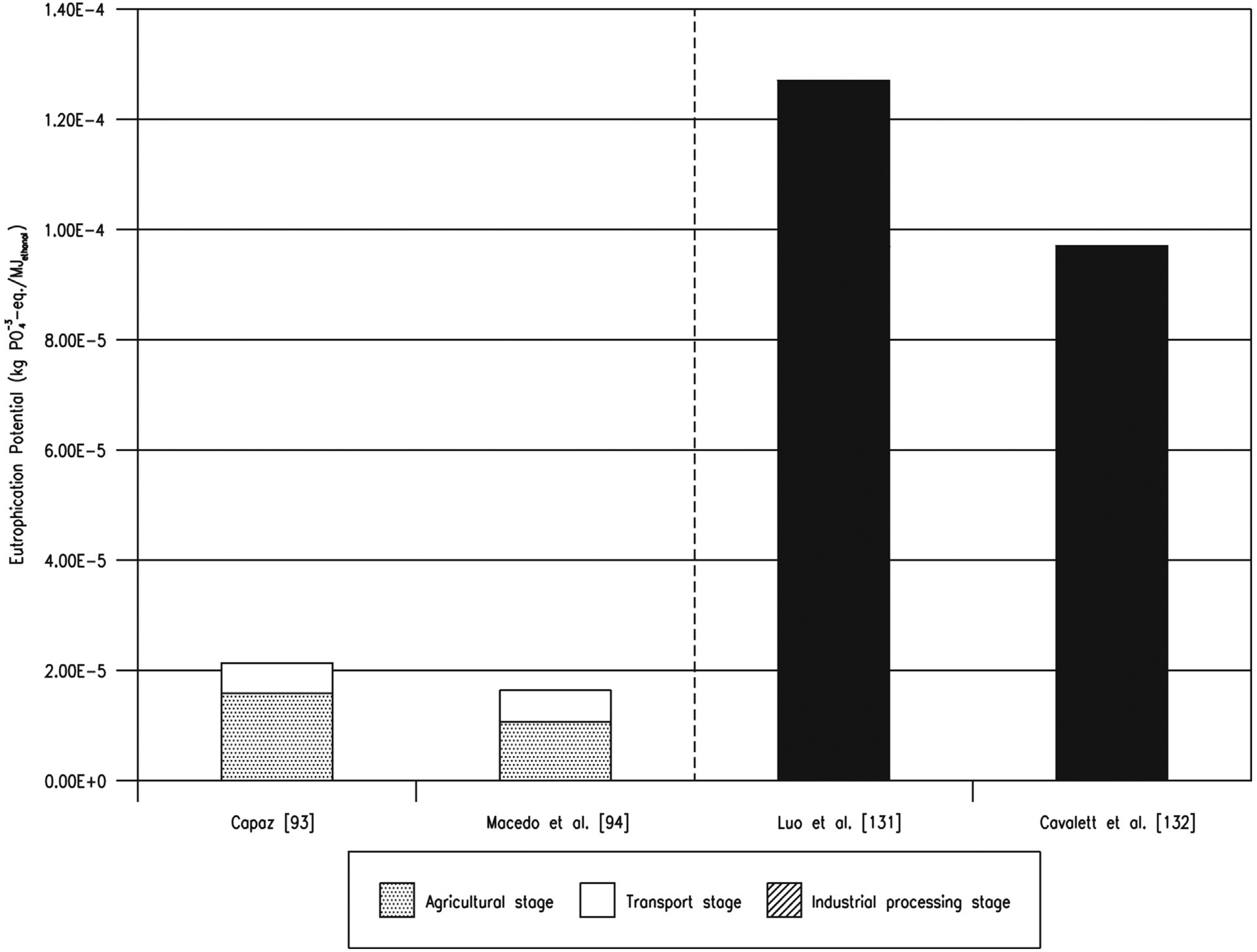
Human Toxicity Potential in life cycle of ethanol production



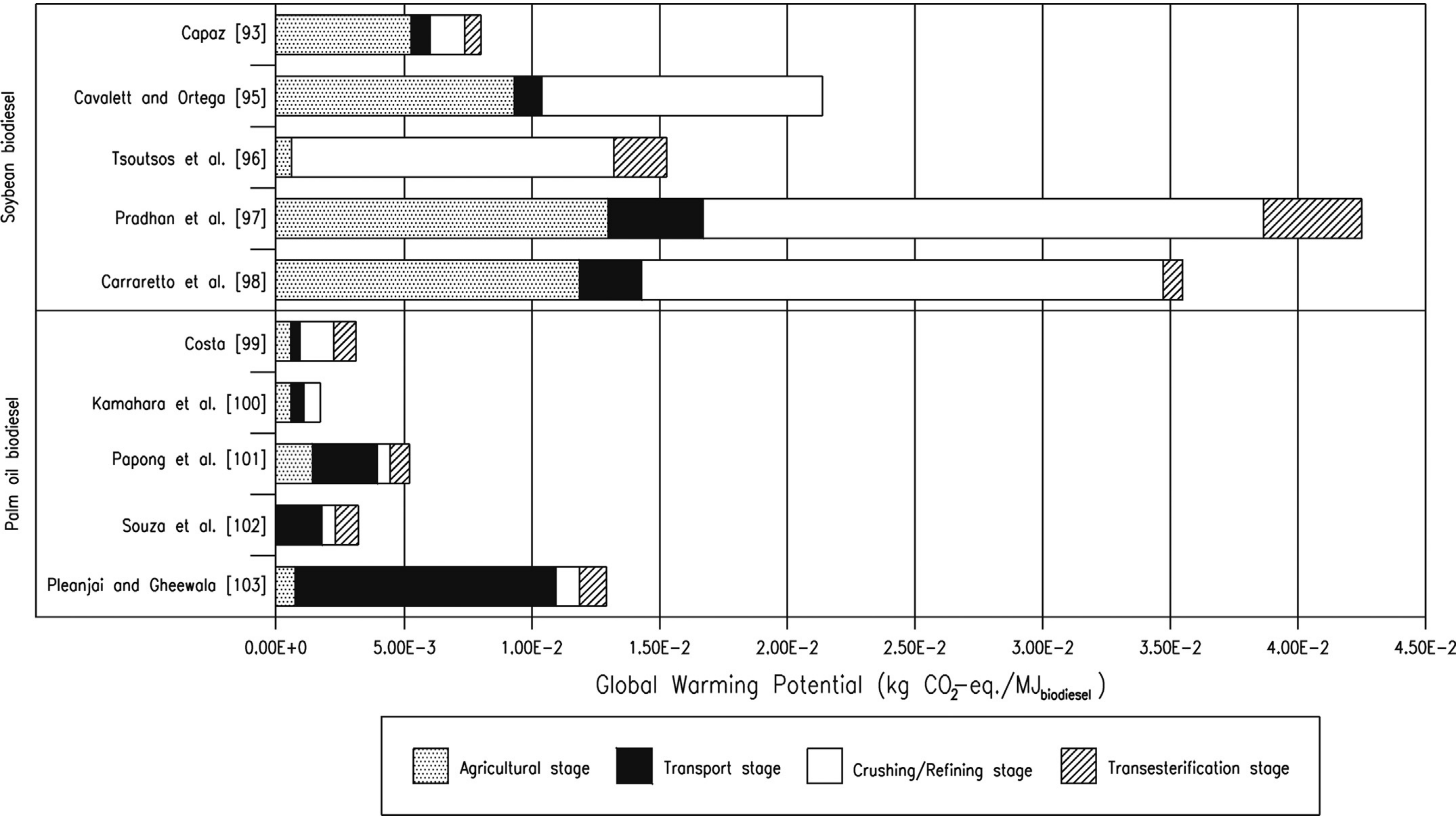
Acidification Potential in life cycle of ethanol production



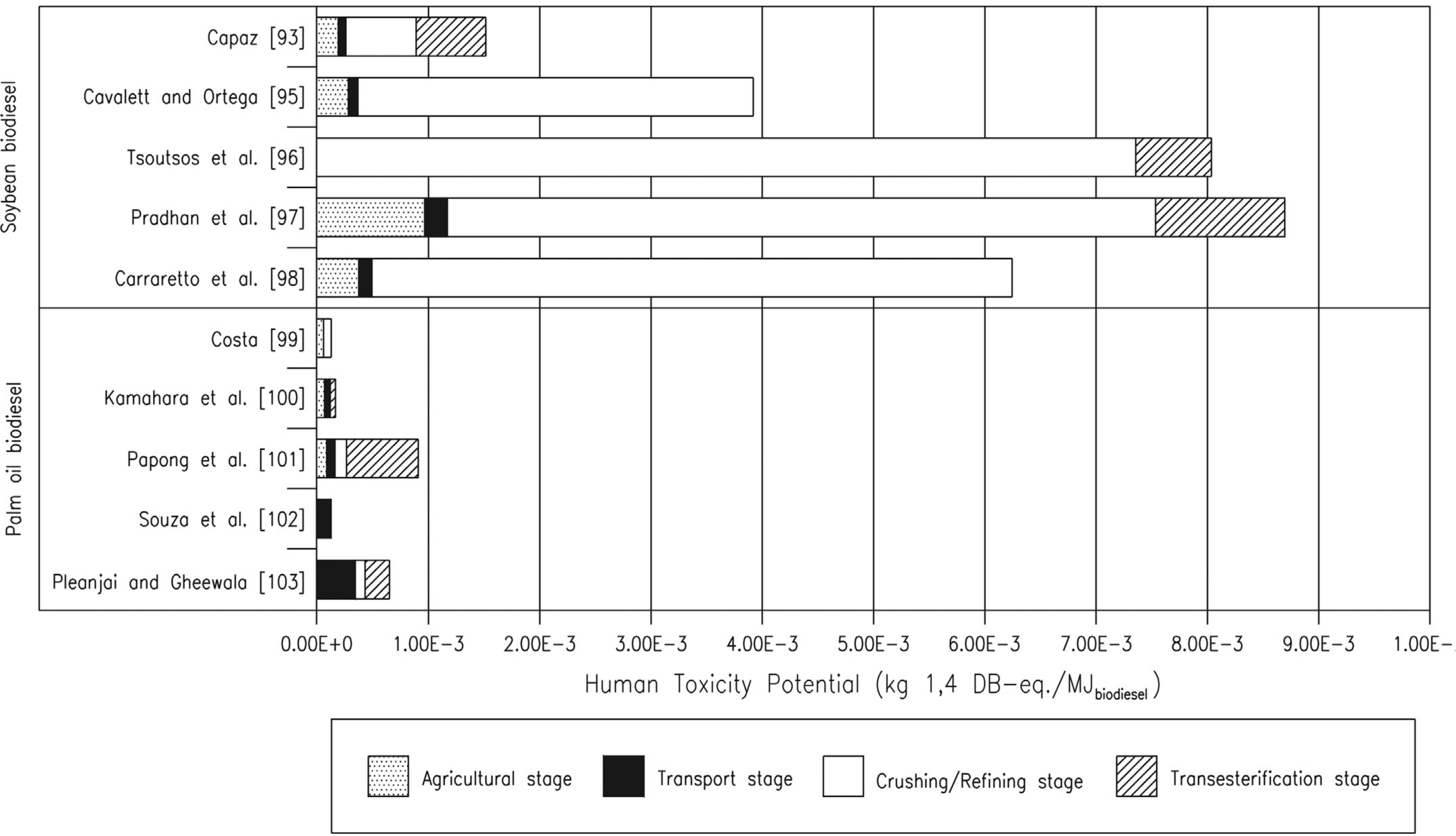
Eutrophication Potential in life cycle of ethanol production



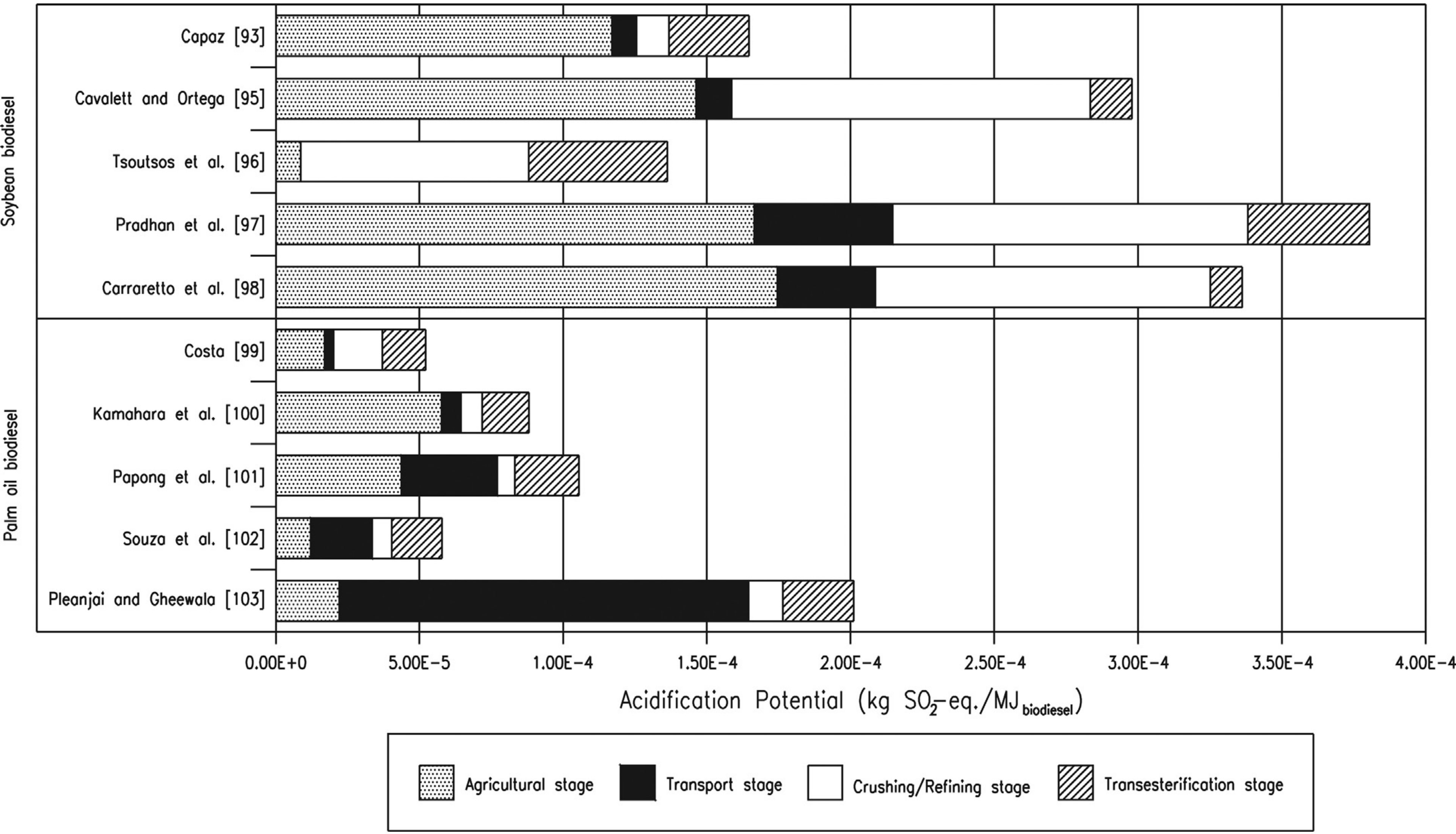
Global Warming Potential in life cycle of biodiesel production



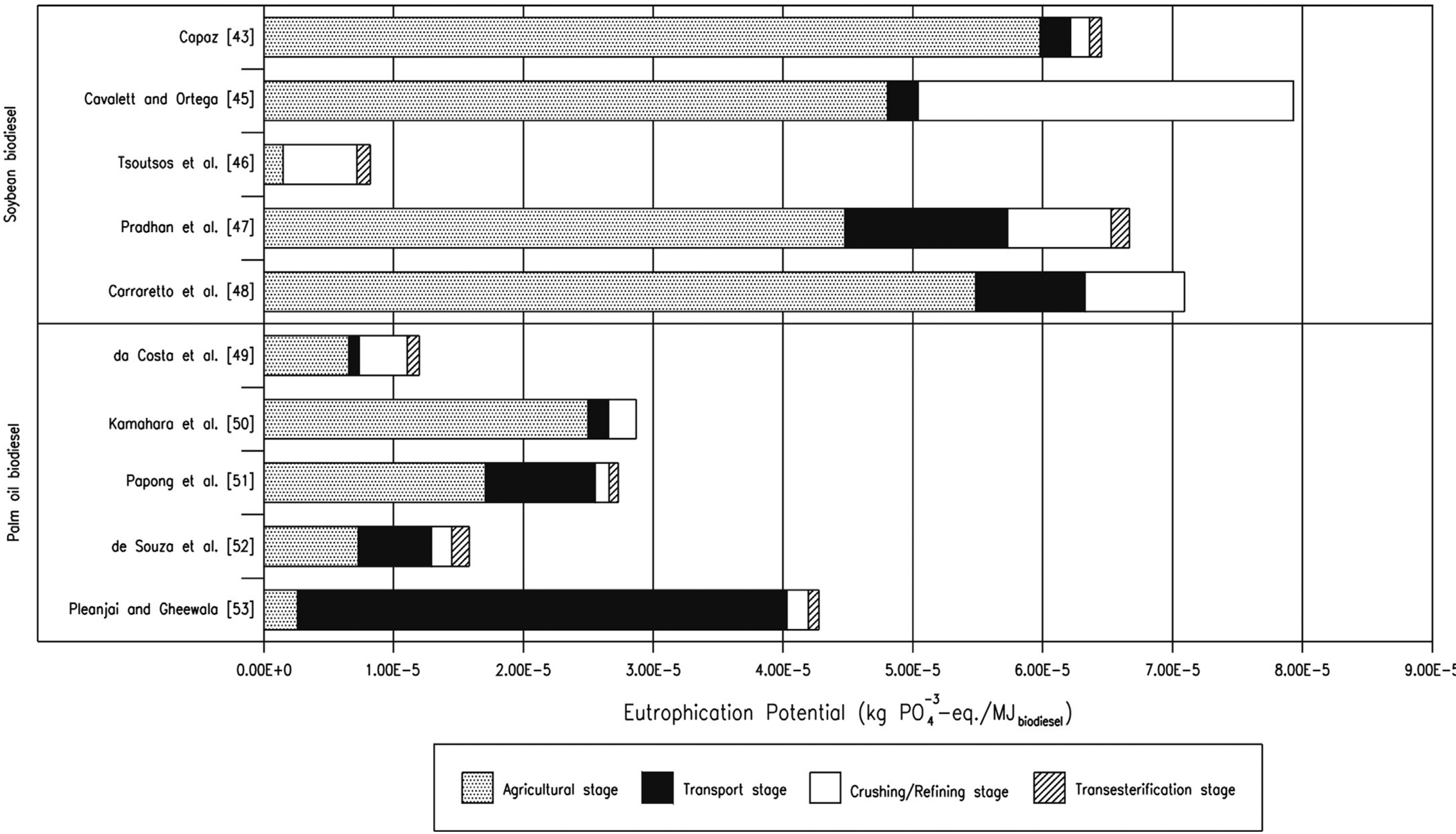
Human Toxicity Potential in life cycle of biodiesel production



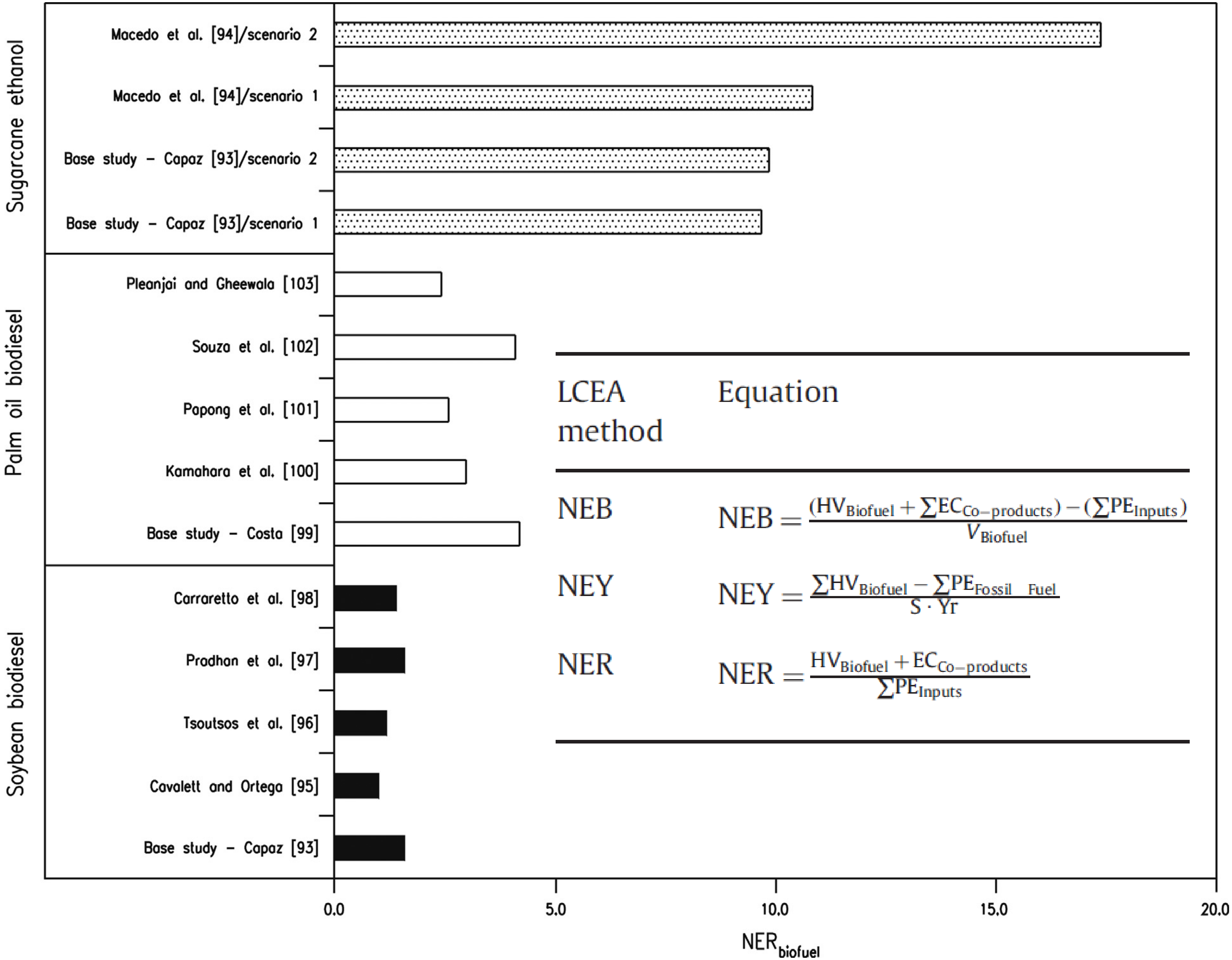
Acidification Potential in life cycle of biodiesel production



Eutrophication Potential in life cycle of biodiesel production

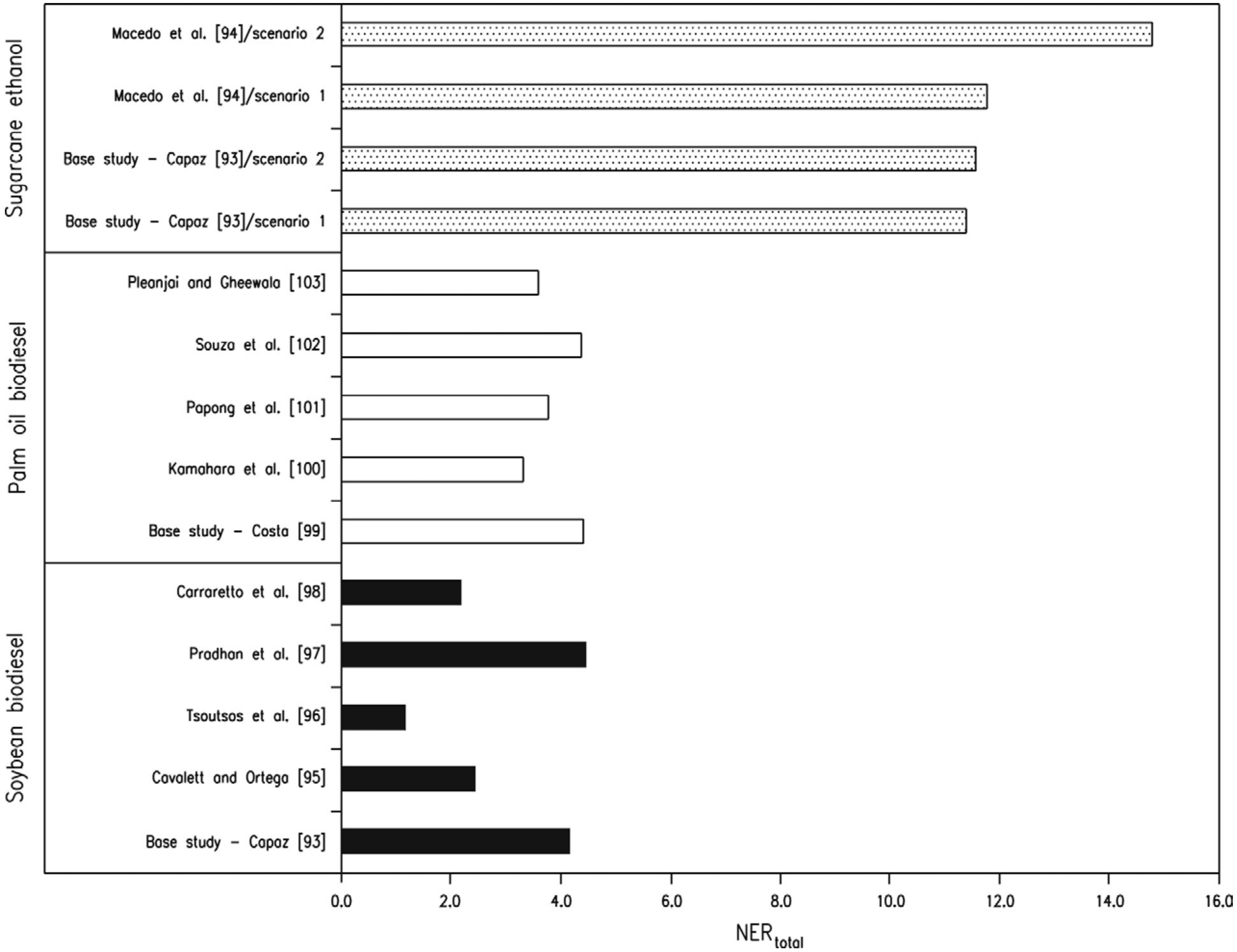


Net Energy Ratio of Biofuel



LCEA method	Equation
NEB	$NEB = \frac{(HV_{Biofuel} + \sum EC_{Co-products}) - (\sum PE_{Inputs})}{V_{Biofuel}}$
NEY	$NEY = \frac{\sum HV_{Biofuel} - \sum PE_{Fossil\ Fuel}}{S \cdot Yr}$
NER	$NER = \frac{HV_{Biofuel} + EC_{Co-products}}{\sum PE_{Inputs}}$

Net Energy Ratio Total



Existing Tools and Constraints in Biofuels Analysis

Energy 36 (2011) 2097–2110

Contents lists available at ScienceDirect

Energy

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

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Issues to consider, existing tools and constraints in biofuels sustainability assessments

Electo E. Silva Lora [a], José C. Escobar Palacio [a], Mateus H. Rocha [a], Maria L. Grillo Renó [a], Osvaldo J. Venturini [a,*], Oscar Almazán del Olmo [b]

[a] NEST – Excellence Group in Thermal Power and Distributed Generation, Federal University of Itajubá, Instituto de Eng. Mecanica – IEM, Av. BPS 1303, CP 50, Itajubá-MG, Brazil
[b] ICIDCA – Instituto Cubano de Investigaciones de los Derivados de la Caña de Azúcar, Via Blanca y Carretera Central 804, San Miguel del Padrón, A.P. 4036, La Habana, Cuba

Claims related to the negative consequences of biofuel programs are frequent; mainly those related to the biofuels/food competition and sustainability. This work contributed for the development of a framework for sustainability indicators as a tool for performance assessment. The most used indicators to measure the biofuels sustainability are: Life Cycle Energy Balance, quantity of fossil energy substituted per hectare, co-product energy allocation, life cycle carbon balance and changes in soil utilization. LCA's of biofuels was compared emphasizing their advantages and disadvantages. Main constraints related to the studied frontiers, as well as the lack of reliable data and their effects was also discussed. Suggestions and recommendations were made to improve existing methodologies for biofuels sustainability evaluation.

Sustainability of biofuels is a multicriterial approach

- **Productivity:** depends on the type of biomass crop, related with the efficiency of the soil utilization. The specific productivity (kg/ha) of the first-generation biofuels vary in a wide range.

- **GHG emissions:** considering that the main justification for biofuel production expansion is the global warming mitigation, it is necessary to verify to which extent the production of a biofuel really reduces the GHG emissions.

- **Land use and carbon stocks changes:** soil organic carbon is of global importance because of its role in the global carbon cycle and, therefore, in the mitigation or worsening of atmospheric levels of GHG.

- **Fertilizer efficiency:** a fraction of the applied fertilizers can be transferred by volatilization to the atmosphere, some of their constituents having a high GWP such as N_2O.

- **Co-product and residues utilization:** as fertilizer, energy, animal feeding, production of chemicals, etc.

Sustainability of biofuels is a multicriterial approach

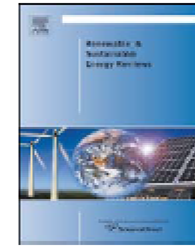
- **Potential for cropland expansion (marginal and low productivity soils):** assessment of the world agro-ecological productivity shows a potential of 700–800 million of hectares available for bioenergy productions.
- **Impacts on water resources (water depletion):** the production of biofuel feedstock and its industrial processing consumes considerable amounts of water.
- **Soil:** soil degradation by erosion and salt increase.
- **Impacts on biodiversity:** this is related with habitat degradation of many species due to deforestation and other land use changes.
- **Costs:** balance between biofuels cost of production and market prices.
- **Land use:** the need of land for other human activities besides energy production, especially for food production.
- **Social issues:** working conditions, rural development, food prices, impact on communities.

Renewable and Sustainable Energy Reviews 13 (2009) 1275–1287

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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



Biofuels: Environment, technology and food security

José C. Escobar [a], Electo S. Lora [a,*], Osvaldo J. Venturini [a], Edgar E. Yáñez [b], Edgar F. Castillo [c], Oscar Almazan [d]

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This work carried out a assessment of the causes of the rise in the demand and production of biofuels. It was discussed different vegetable raw materials sources and technological paths to produce biofuels, as well as issues regarding production cost and the relation of their economic feasibility with oil international prices. The environmental impacts of programs that encourage biofuel production, farmland land requirements and the impacts on food production are also discussed, considering the LCA as a tool. It was concluded that the rise in the use of biofuels is inevitable and that international cooperation, regulations and certification mechanisms must be established regarding the use of land, the mitigation of environmental and social impacts caused by biofuel production. It is also mandatory to establish appropriate working conditions and decent remuneration for workers of the biofuels production chain

Life Cycle Energy Analysis of Biodiesel Production

Renewable Energy 34 (2009) 2905–2913

Contents lists available at ScienceDirect

Renewable Energy

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

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Technical note

The energy balance in the Palm Oil-Derived Methyl Ester (PME) life cycle for the cases in Brazil and Colombia

Edgar Eduardo Yáñez Angarita[a,*], Electo Eduardo Silva Lora[b], Rosélis Ester da Costa[b], Ednildo Andrade Torres[c]

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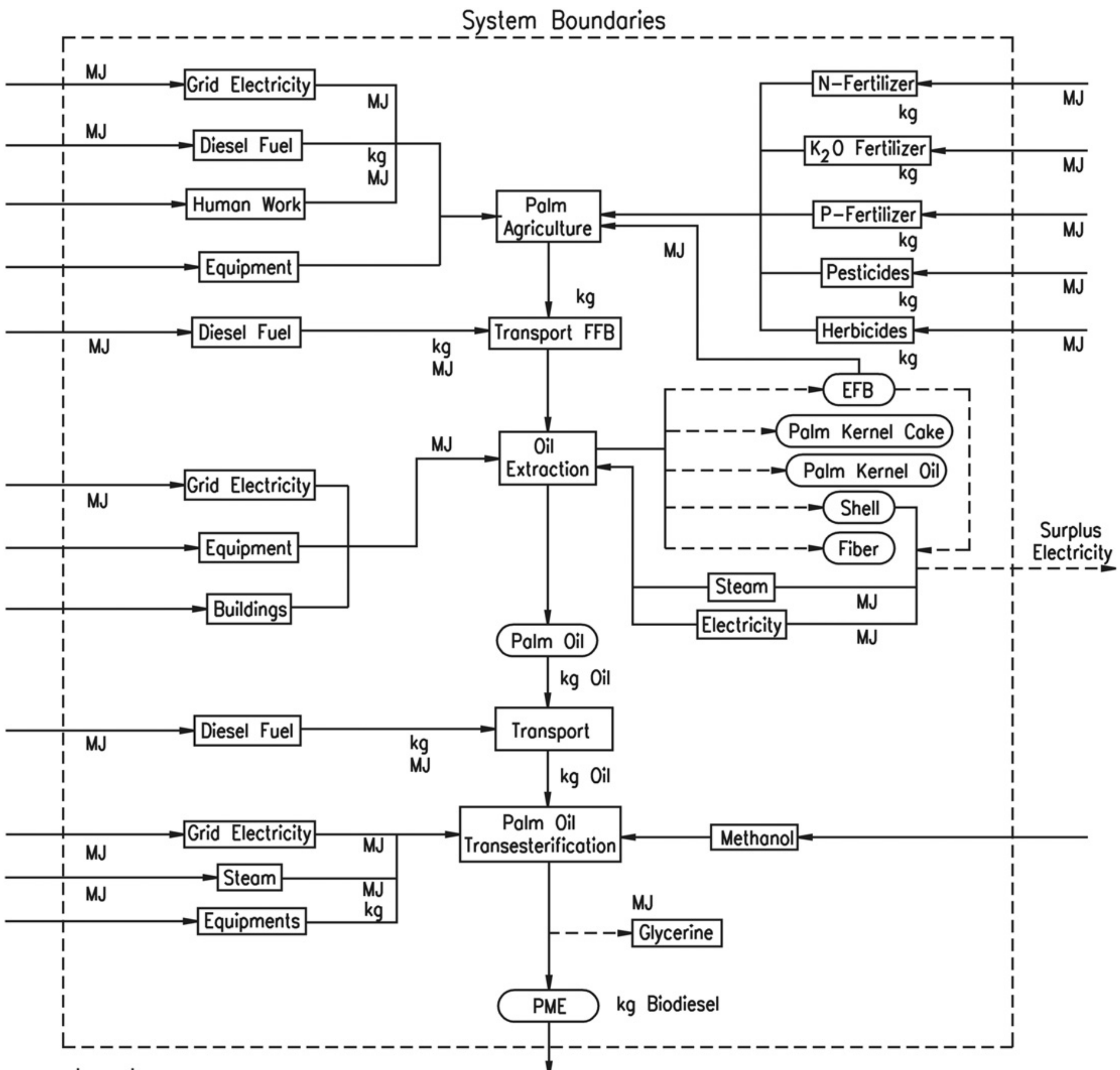
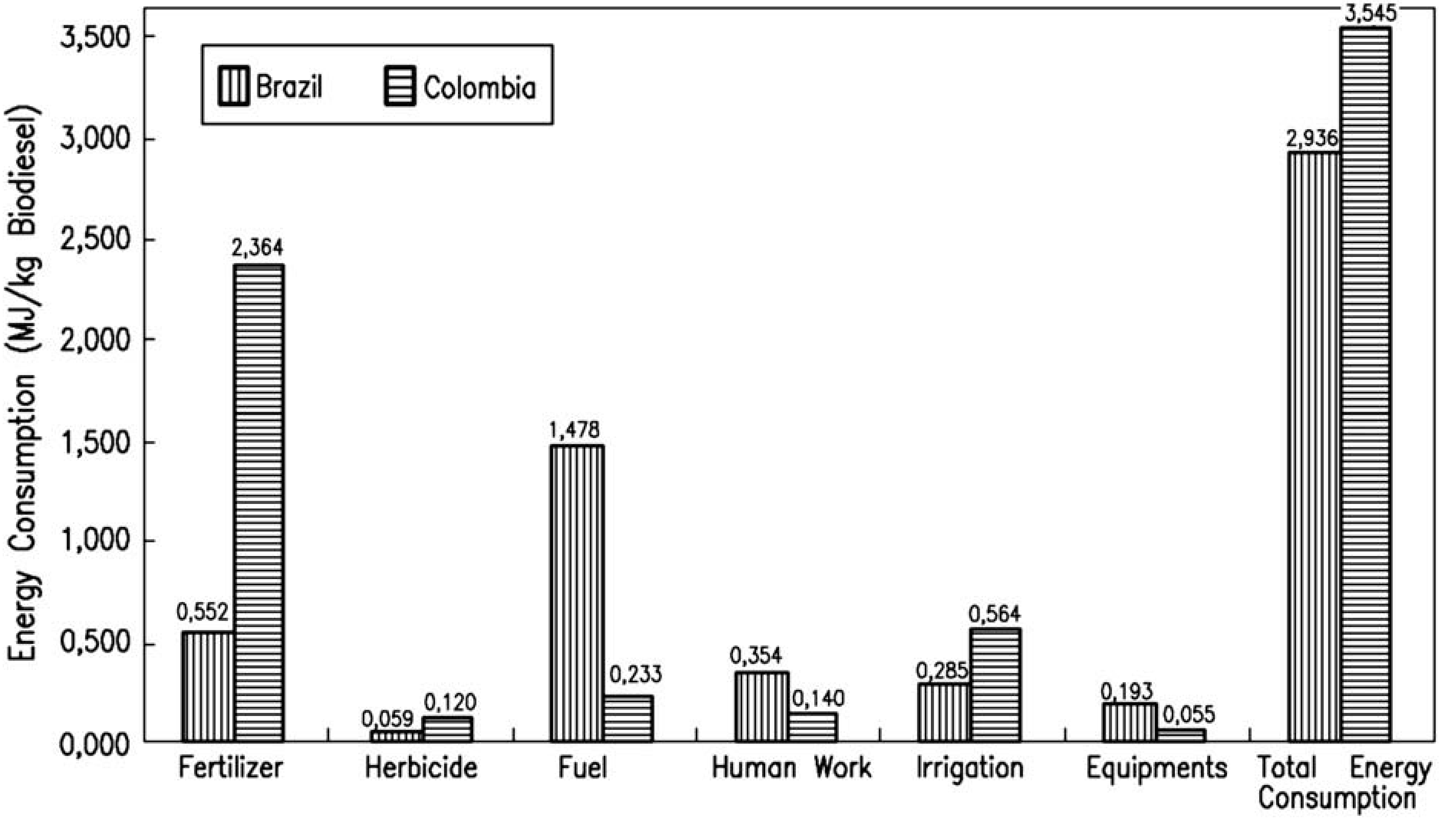
The Output/Input energy relation in the biodiesel production life cycle can be an important indicator of the techno-economic and environmental feasibility evaluation of production of biodiesel from different oleaginous plants. Due to increasing environmental concerns about the emissions from fuel-derived atmospheric pollutants, alternative sources of energy have been receiving greater attention. This work does not look to carry out a complete LCA but rather just to focus on the energy balance in the Palm Oil-Derived Methyl Ester life cycle, taking into account practices in Brazil and Colombia. This work will show the differences between the results attained for the two cases. The Output/Input energy relation for the evaluated case studies ranged from 3.8 to 5.7, with an average value of 4.8.

PME System Boundaries

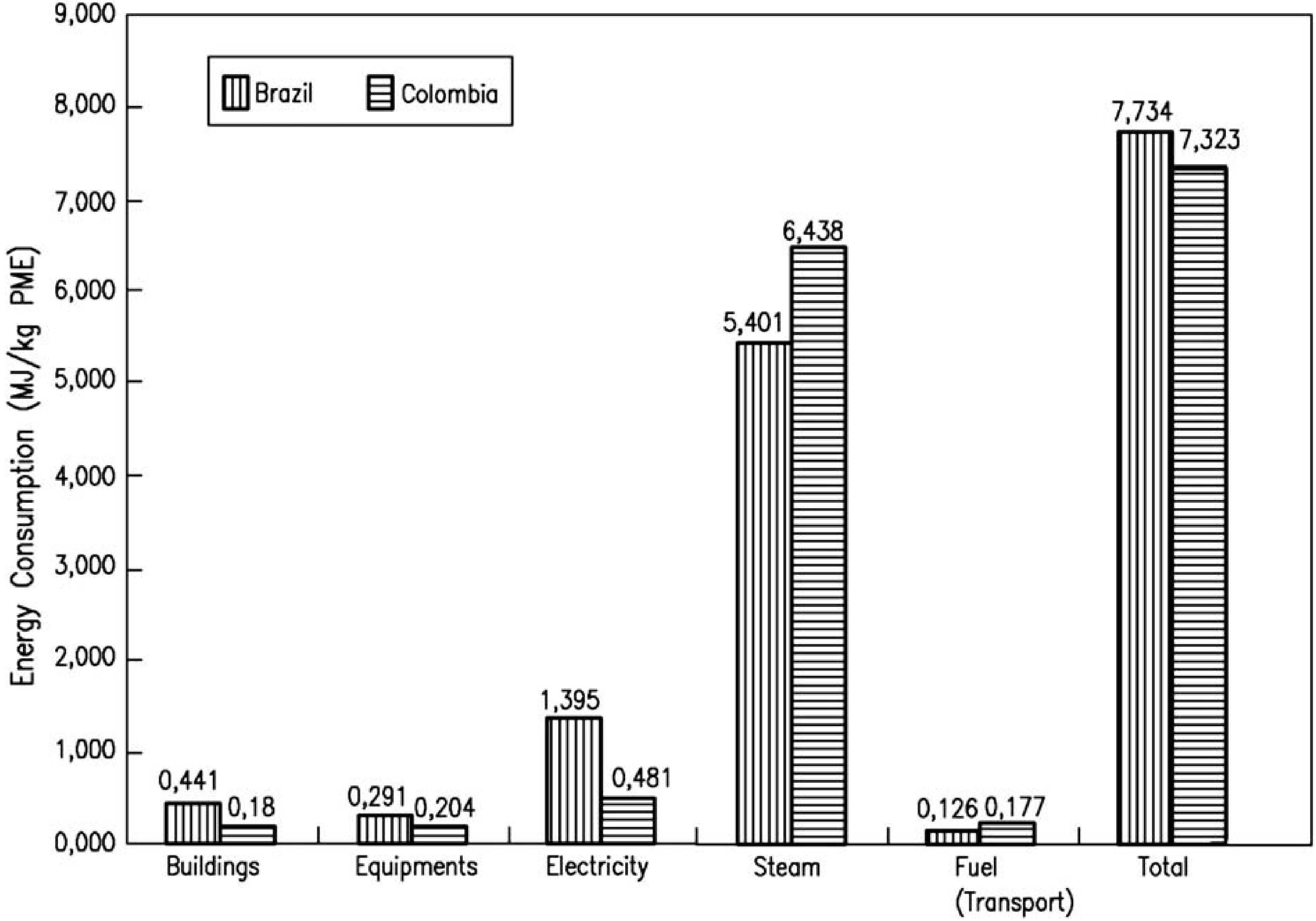


Legend:
PME: Palm Oil–Derived Methyl Ester
EFB: Empty Fruit Brunches
FFB: Fresh Fruit Brunches

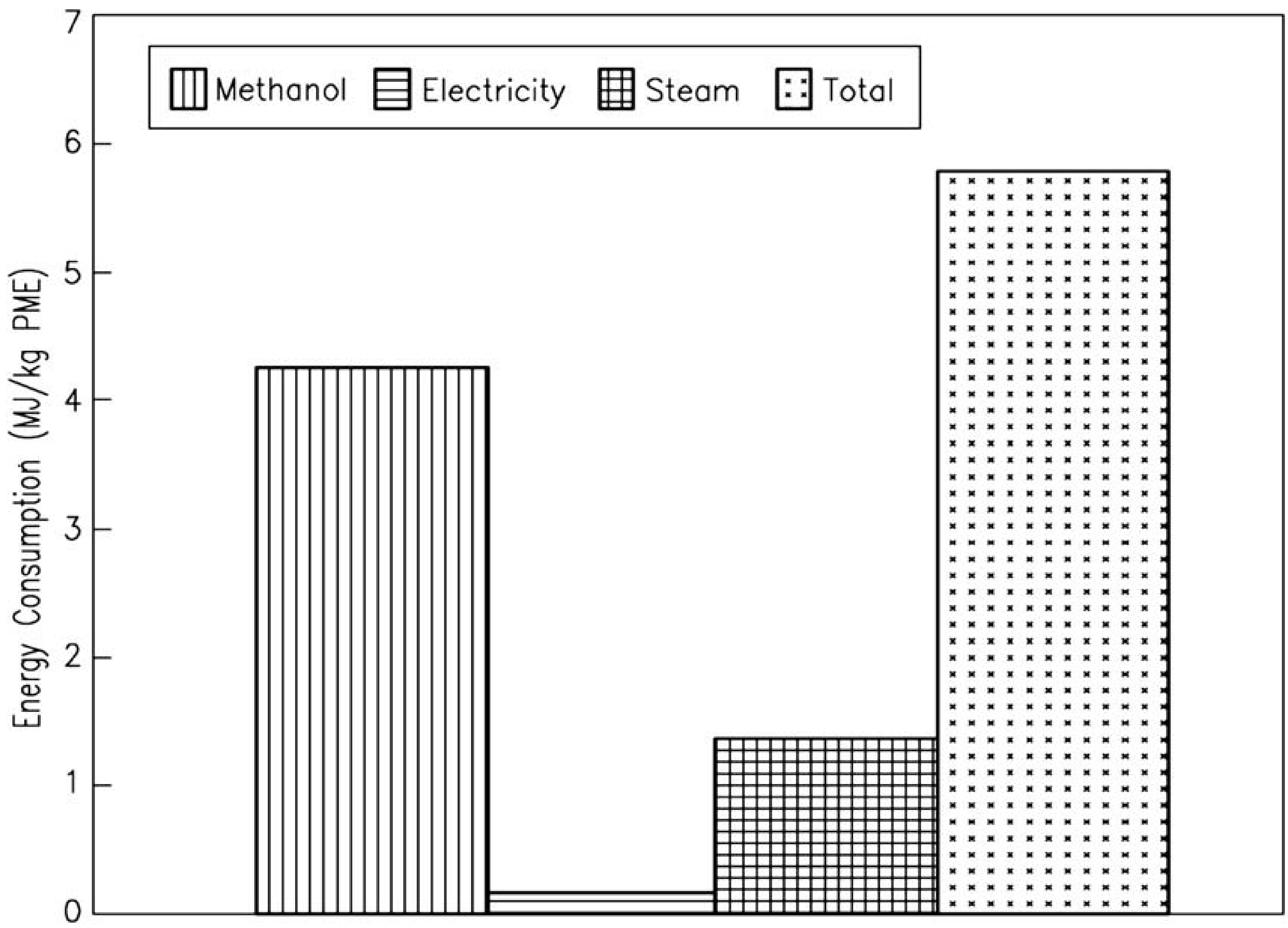
Energy Consumption related to Fuels and Agrochemicals for Agricultural Stage Production of Biodiesel



Energy Consumption related to Fuels and Steam/Electricity for Transesterification Stage to Biodiesel Production



Energy consumption in methanol, steam and electricity in the transesterification stage



NEST Experience in Life Cycle Assessment (LCA) Related With Residues Energy Conversion

Resources, Conservation and Recycling 87 (2014) 8–20

Contents lists available at ScienceDirect

Resources, Conservation and Recycling

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

Techno-economic analysis and environmental impact assessment of energy recovery from Municipal Solid Waste (MSW) in Brazil

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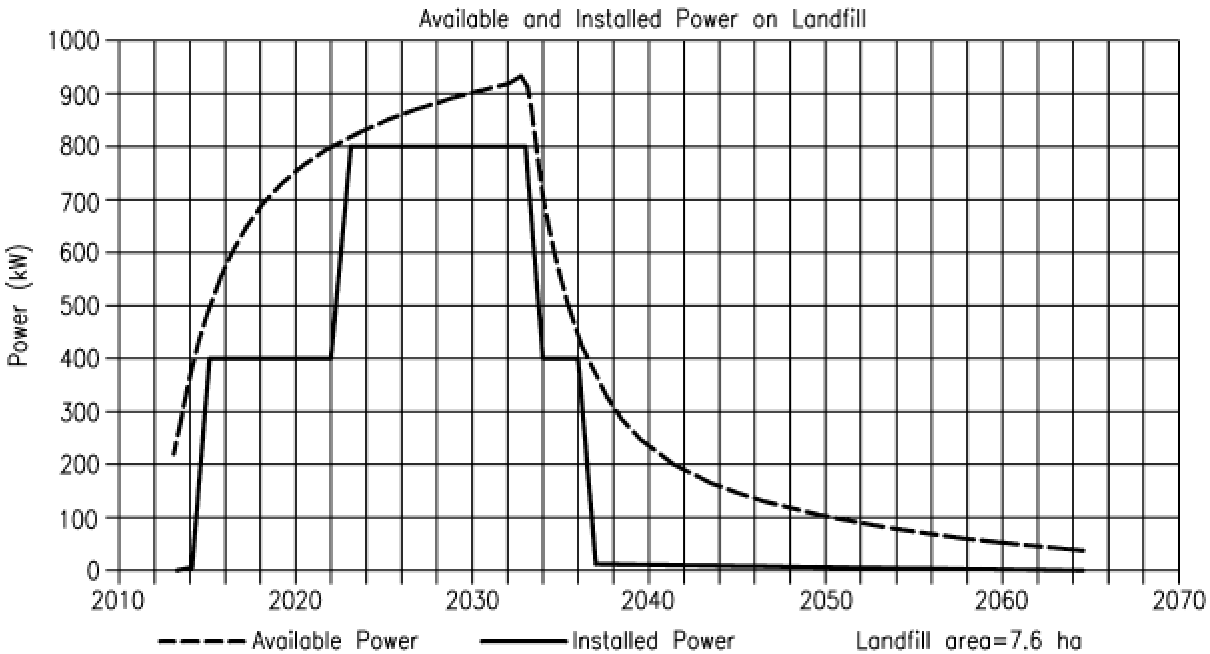
This work compared from a techno-economic and environmental point of view, different alternatives to the energy recovery from the MSW generated in Brazilian cities. The environmental analysis was carried out using current data collected in Betim, a 450,000 inhabitants city that currently produces 200 tones of MSW/day. Four scenarios were designed, whose environmental behavior were studied applying the LCA methodology. The results show the landfill systems as the worst waste management option and that a significant environmental savings is achieved when a wasted energy recovery is done. The best option, which presented the best performance based on considered indicators, is the direct combustion of waste as fuel for electricity generation.

Energy and economic performance for the 100,000 inhabitants case (landfill option)



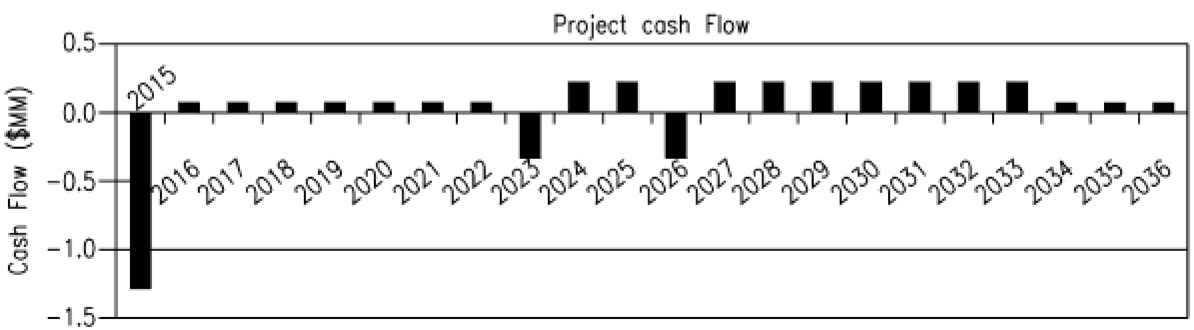
Schedule for generator modules

Modules	Power (kW)	Start of operation	End of operation
Module 1	400	2015	2025
Module 2	400	2023	2033
Module 3	400	2026	2036

Total energy produced: 103,154 MWh
Biogas generator sets: Caterpillar CG132-8
supplied by biogas/Electric Power: 400 kW_e
Electrical efficiency: 42.8%

Landfill Biogas Utilization Specification:

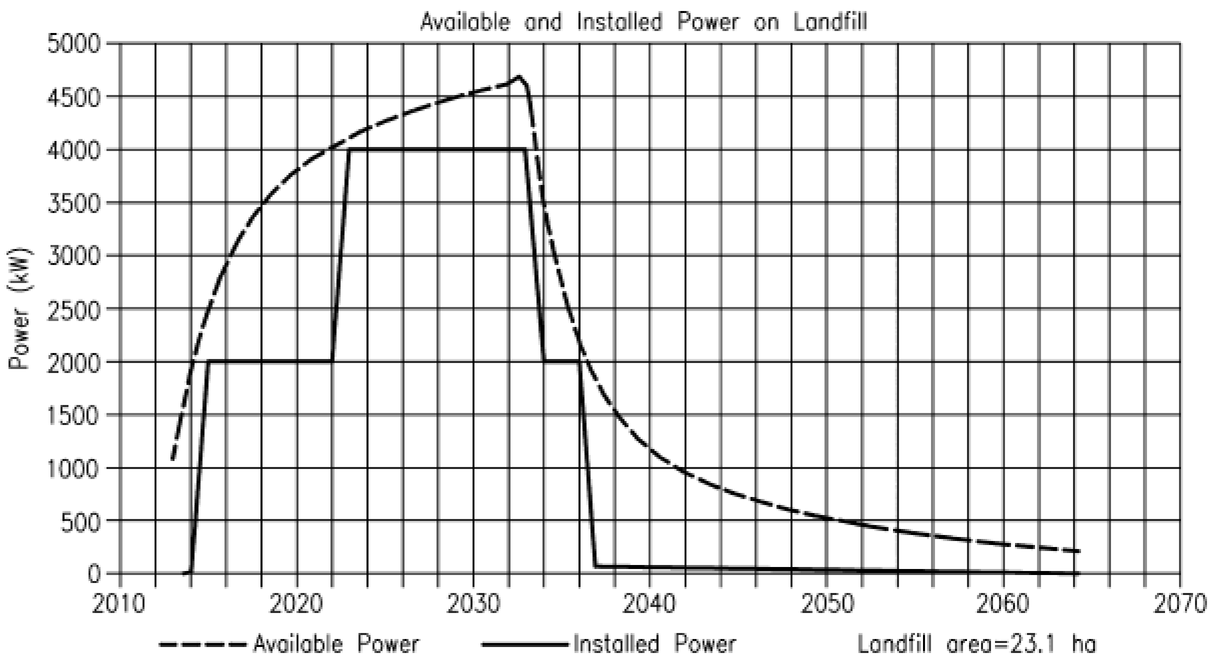
Collection system efficiency: 75.0%
Fugitive biogas emissions: 25.0%
Biogas used for energy generation: 42.5%
Biogas send to flares: 32.5%

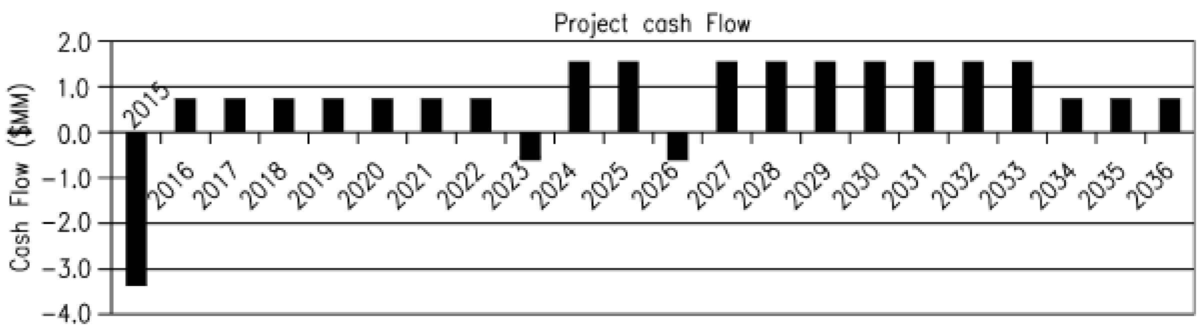


Economic Results:

NPV: $ -659,204.13	
IRR: 0.4%	
Capital costs	$ 1,828,329.86
O&M costs	$ 2,059,040.76
Energy sales	$ 3,130,335.93
CER's sales	$ 97,830.56
CER's costs	$ 694,783.67
LCOE	$ 82.60/MWh

Energy and economic performance for the 500,000-inhabitant scenario (landfill option)





Schedule for generator modules

Modules	Power (kW)	Start of operation	End of operation
Module 1	2000	2015	2025
Module 2	2000	2023	2033
Module 3	2000	2026	2036

Total energy produced: 515,771 MWh
Biogas generator sets: Caterpillar CG170–20
supplied by biogas/Electric Power: 2000 kW_e
Electrical efficiency: 42.9%

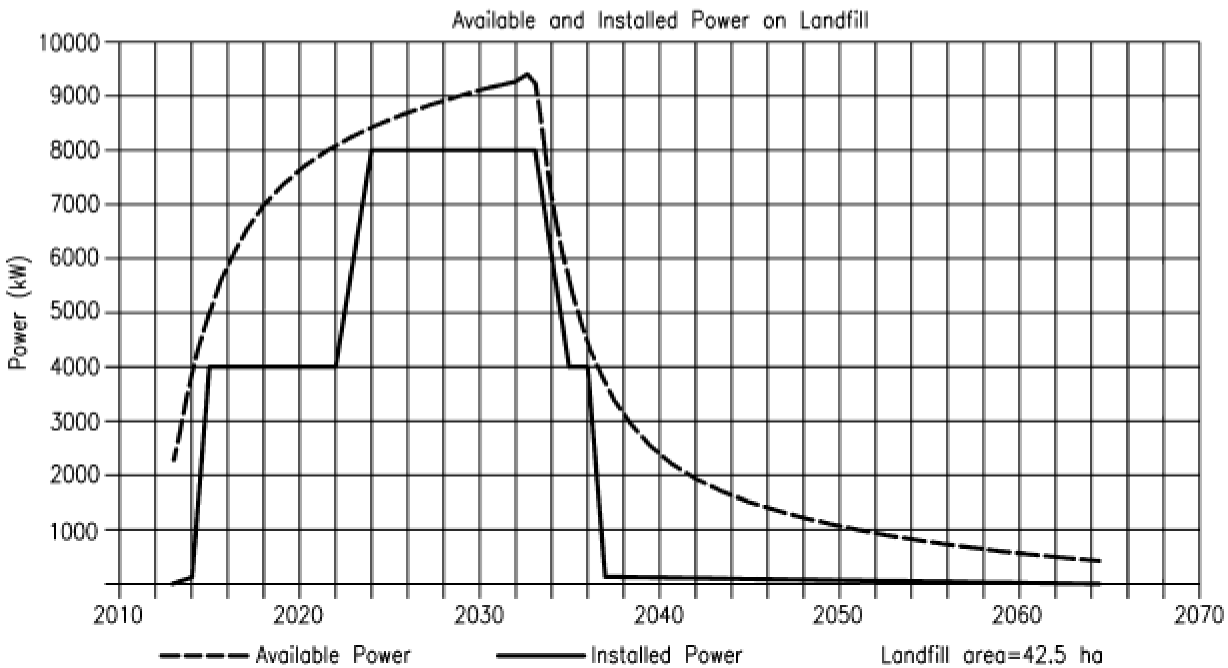
Landfill Biogas Utilization Specification:

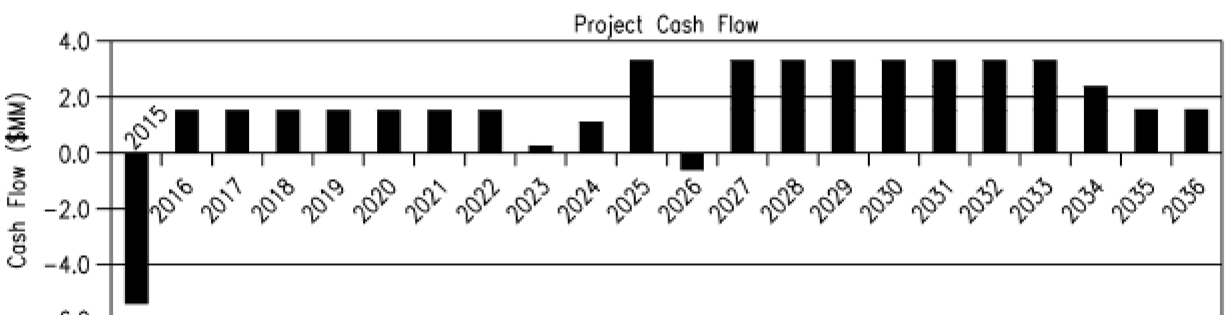
Collection system efficiency: 75.0%
Fugitive biogas emissions: 25.0%
Biogas used for energy generation: 42.4%
Biogas send to flares: 32.6%

Economic Results:

NPV: $ 3,004,678.30	
IRR: 15.6%	
Capital costs	$ 5,937,432.82
O&M costs	$ 7,198,721.32
Energy sales	$ 15,651,679.66
CER's sales	$ 489,152.78
CER's costs	$ 1,457,208.34
LCOE	$ 49.00/MWh

Energy and economic performance for the 1,000,000 inhabitant's scenario (landfill option)





Schedule for generator modules

Modules	Power (kW)	Start of operation	End of operation
Module 1	2000	2015	2025
Module 2	2000	2015	2025
Module 3	2000	2023	2033
Module 4	2000	2024	2034
Module 5	2000	2026	2036
Module 6	2000	2026	2036

Total energy produced: 1,031,542 MWh
Biogas generator sets: Caterpillar CG170-20
supplied by biogas/Electric Power: 2000 kW_e
Electrical efficiency: 42.9%

Landfill Biogas Utilization Specification:

Collection system efficiency: 75.0%
Fugitive biogas emissions: 25.0%
Biogas used for energy generation: 42.4%
Biogas send to flares: 32.6%

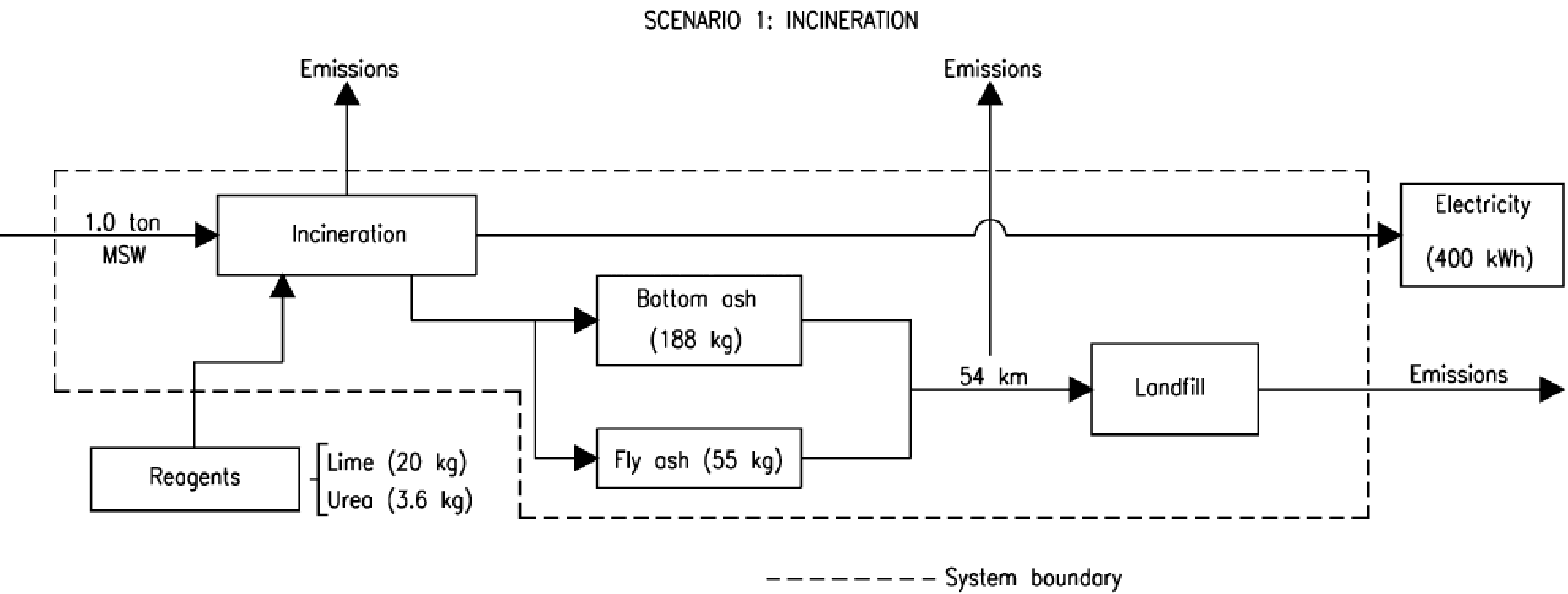
Economic Results:

NPV: $ 8,793,264.25	
IRR: 21.5%	
Capital costs	$ 10,504,505.26
O&M costs	$ 12,686,389.02
Energy sales	$ 31,006,423.99
CER's sales	$ 977,734.54
CER's costs	$ 2,165,501.11
LCOE	$ 41.15/MWh

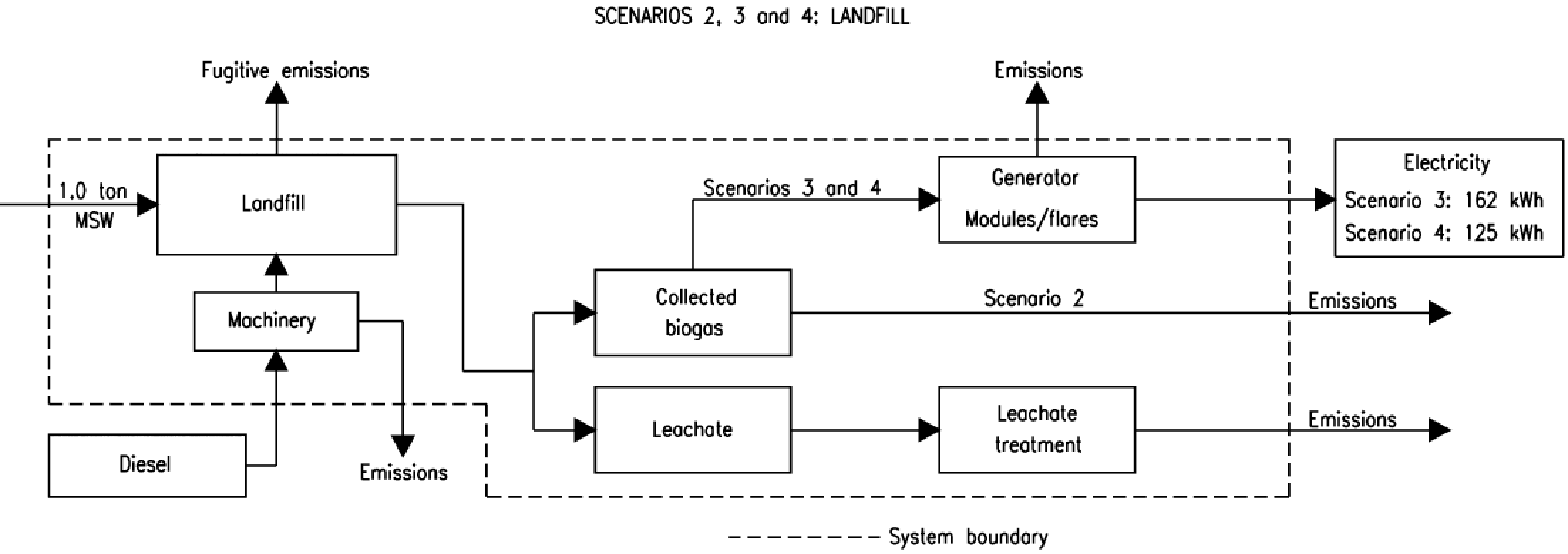
Results of the Waste-to-Energy facility cases

100,000 Inhabitants Scenario		500,000 Inhabitants Scenario		1,000,000 Inhabitants Scenario	
Power output	2350 kW	Power output	11,930 kW	Power output	23,880 kW
Energy produced	488,800 MWh	Energy produced	2,481,440 MWh	Energy produced	4,967,040 MWh
Economic Results		Economic Results		Economic Results	
NPV	$ –73,857,512	NPV	$ –189,861,280	NPV	$ –269,667,068
Total COI	$ 28,952,471	Total COI	$ 104,609,442	Total COI	$ 182,181,518
O&M costs	$ 71,733,149	O&M costs	$ 220,452,589	O&M Costs	$ 358,107,897
Energy sales	$ 14,451,102	Energy sales	$ 73,362,401	Energy Sales	$ 146,847,789
WTB	$ 12,285,580	WTB	$ 61,379,339	WTB	$ 122,855,797
CER' sales	$ 91,427	CER' sales	$ 459,011	CER' sales	$ 918,761
CER' cost	$ 457,516	CER' cost	$468,544	CER' cost	$ 482,336
LCOE [$/MWh]	397.00	LCOE [$/MWh]	233.40	LCOE [$/MWh]	184.40

Life Cycle Assessment Boundaries of the Scenario 1



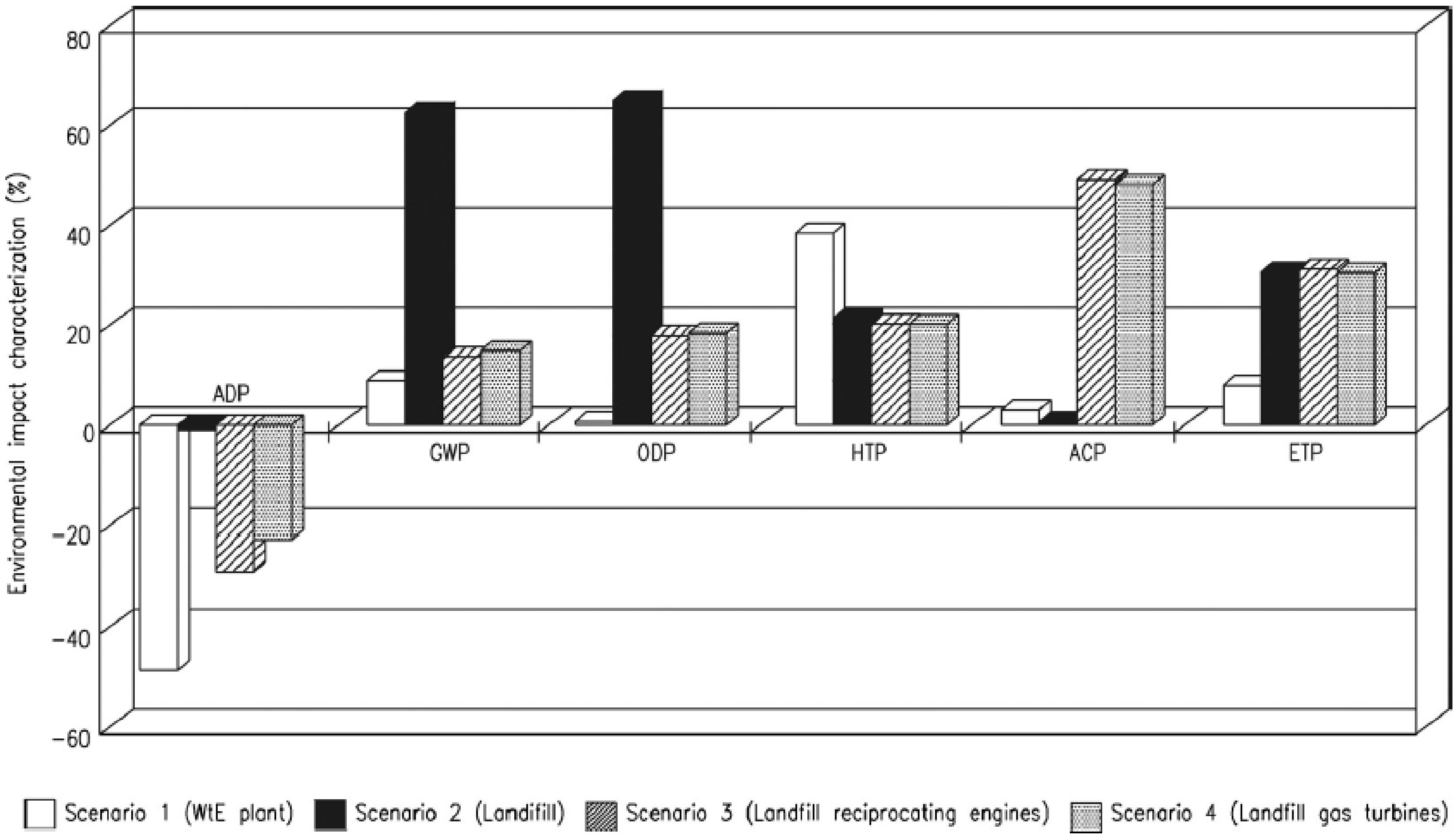
Life Cycle Assessment Boundaries of the Scenario 2, 3 and 4



Emissions characteristics of biogas combustion in different systems

	Biogas Burning Systems emissions and removal efficiency		
	Pollutant	Value	Unit
Flare	NO_x	19.3	µg/kJ
	CO	22.54	µg/kJ
	Particulates	7.28	µg/kJ
	Dioxins/Furans	0.205	pg TEQ/kJ
	Pollutants removal efficiency	99.7	%
IC Engine	NO_x	1077	µg/kJ
	CO	784.2	µg/kJ
	Particulates	21.5	µg/kJ
	Pollutants removal efficiency	97.2	%
Gas Turbines	NO_x	125.9	µg/kJ
	CO	393.2	µg/kJ
	Particulates	38.23	µg/kJ
	Pollutants removal efficiency	94.4	%

LCA characterization for evaluated scenarios



Scenario	Energy recovery		LCA characterization					
			ADP	GWP	ODP	HTP	ACP	ETP
Units	kWh/tonne MSW	%	kg Sb-eq.	kg CO_2-eq.	kg CFC-11-eq.	kg 1,4 DB-eq	kg SO_2-eq.	kg PO_4^{-3}-eq
Scenario 1 – WtE	400.0	18.0	–0.21	285.0	0.00	331.9	0.68	0.66
Scenario 2 – Landfill	0.0	0.0	0.00	2052	0.0132	182.4	0.00	2.53
Scenario 3 – Landfill reciprocating ICE	162.0	7.4	–0.12	464.0	0.0036	175.7	11.87	2.57
Scenario 4 – gas turbines	125.0	5.7	–0.10	478.0	0.0037	175.4	11.65	2.51

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Sugarcane biorefineries: Case studies applied to the Brazilian sugar–alcohol industry

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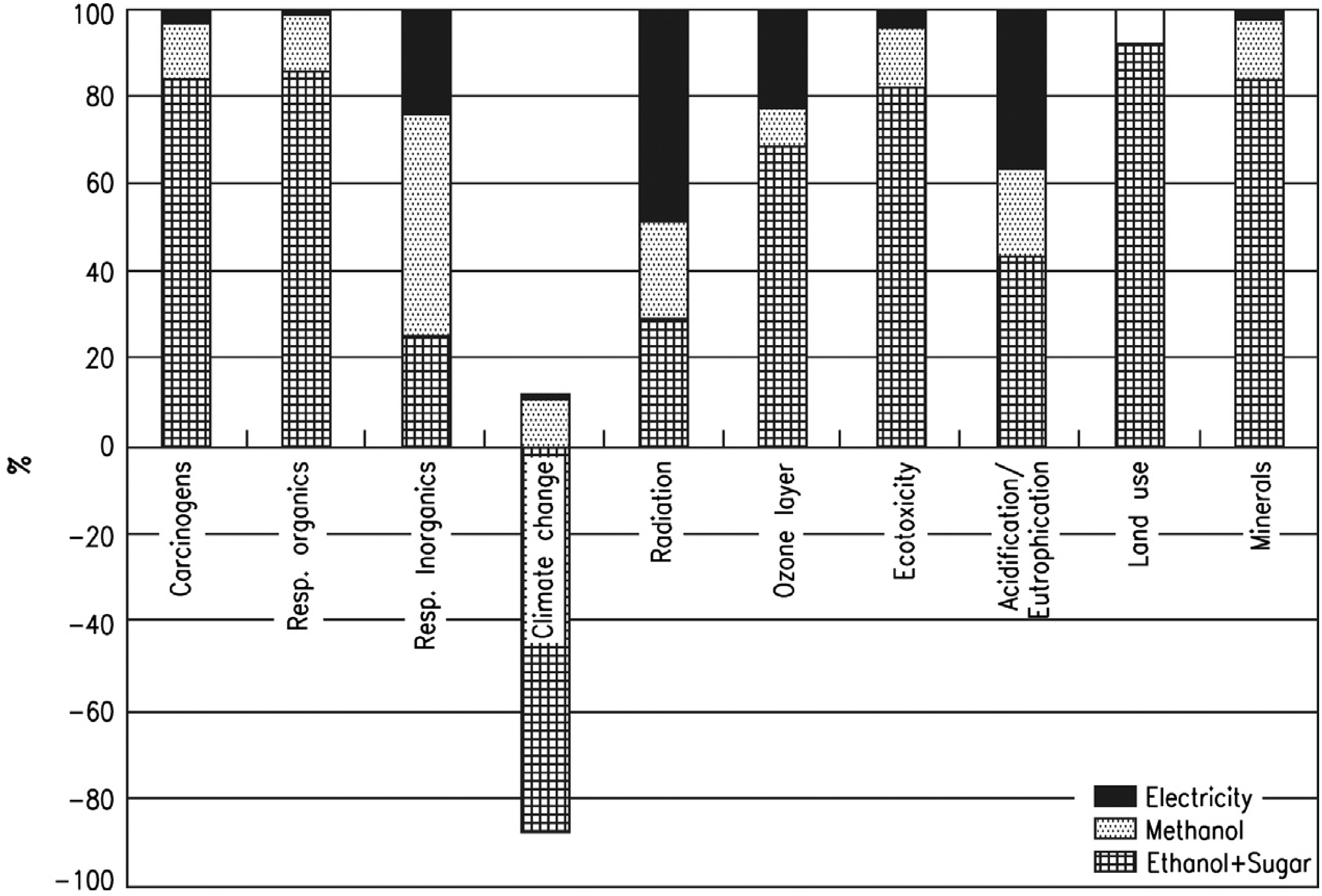
The biorefineries can reach the higher overall yield from the raw materials, with the lowest environmental impact, at minimum energy input and giving the maximum of the energy output. The biorefinery is the true valuable option of a wide diversification, with by-products like the single cell protein and biogas from the distillery stillage, new oxidants like methanol, second generation biofuels, biobutanol, etc. In this context this paper presents a study of five different configurations of biorefineries. Each case study being a system based on an autonomous distillery or sugar mill with an annexed distillery and coproduction of methanol from bagasse. The paper includes the use of sugarcane harvest residues (mainly sugarcane trash) and a BIG–GT plant as alternatives to fulfill the energy demands of the complex

Environmental impacts of the products by impact category



International Sugar Journal, Vol 112, Issue 1343, 2010.

Use of the life cycle assessment (LCA) for comparison of the environmental performance of four alternatives for the treatment and disposal of bioethanol stillage †

By M.H. Rocha [1*], E.E.S. Lora [1], O.J. Venturinl [1], J.C.P. Escobar [1], J.J.C.S. Santos [1] and A.G. Moura [2]

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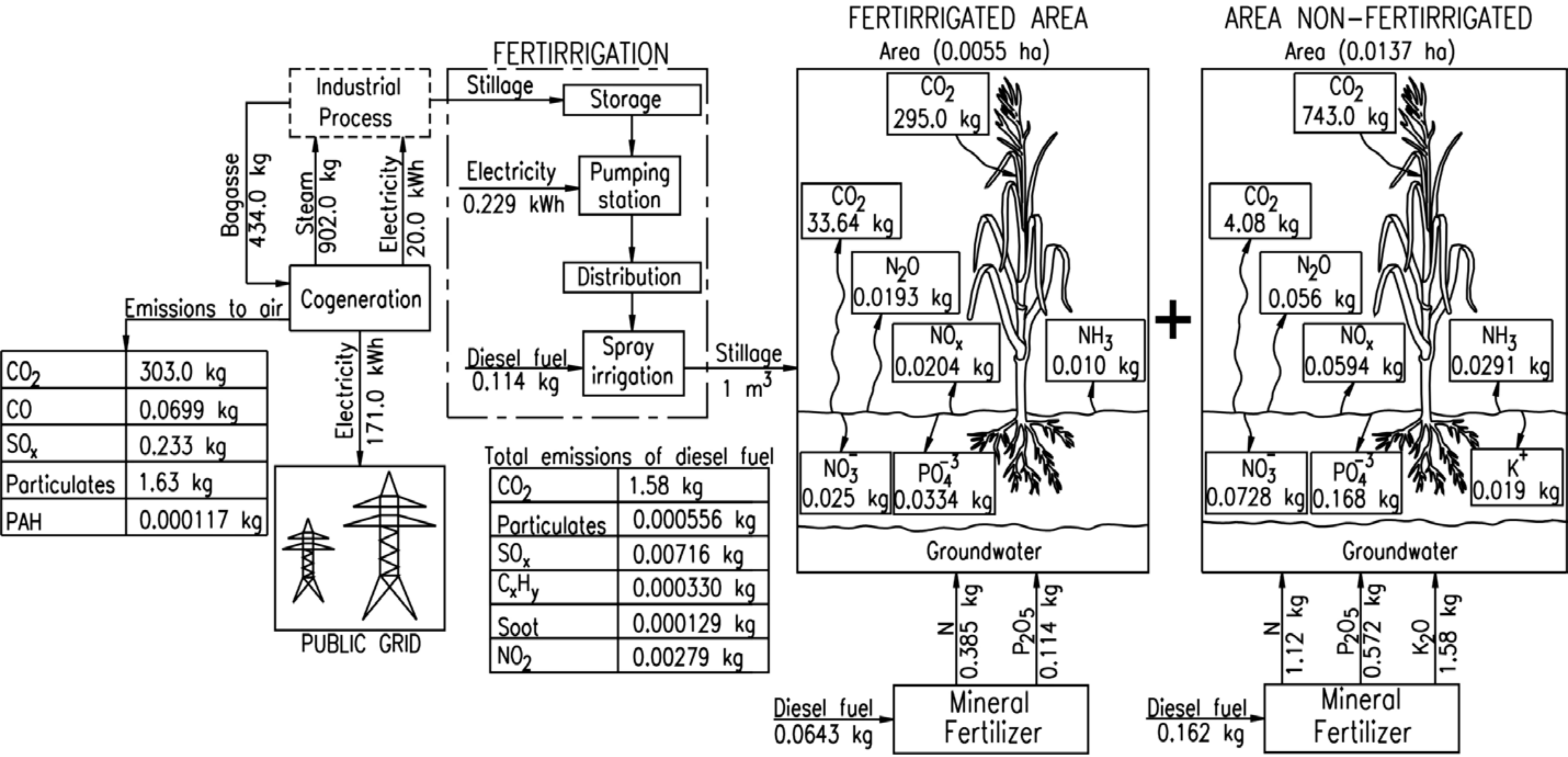
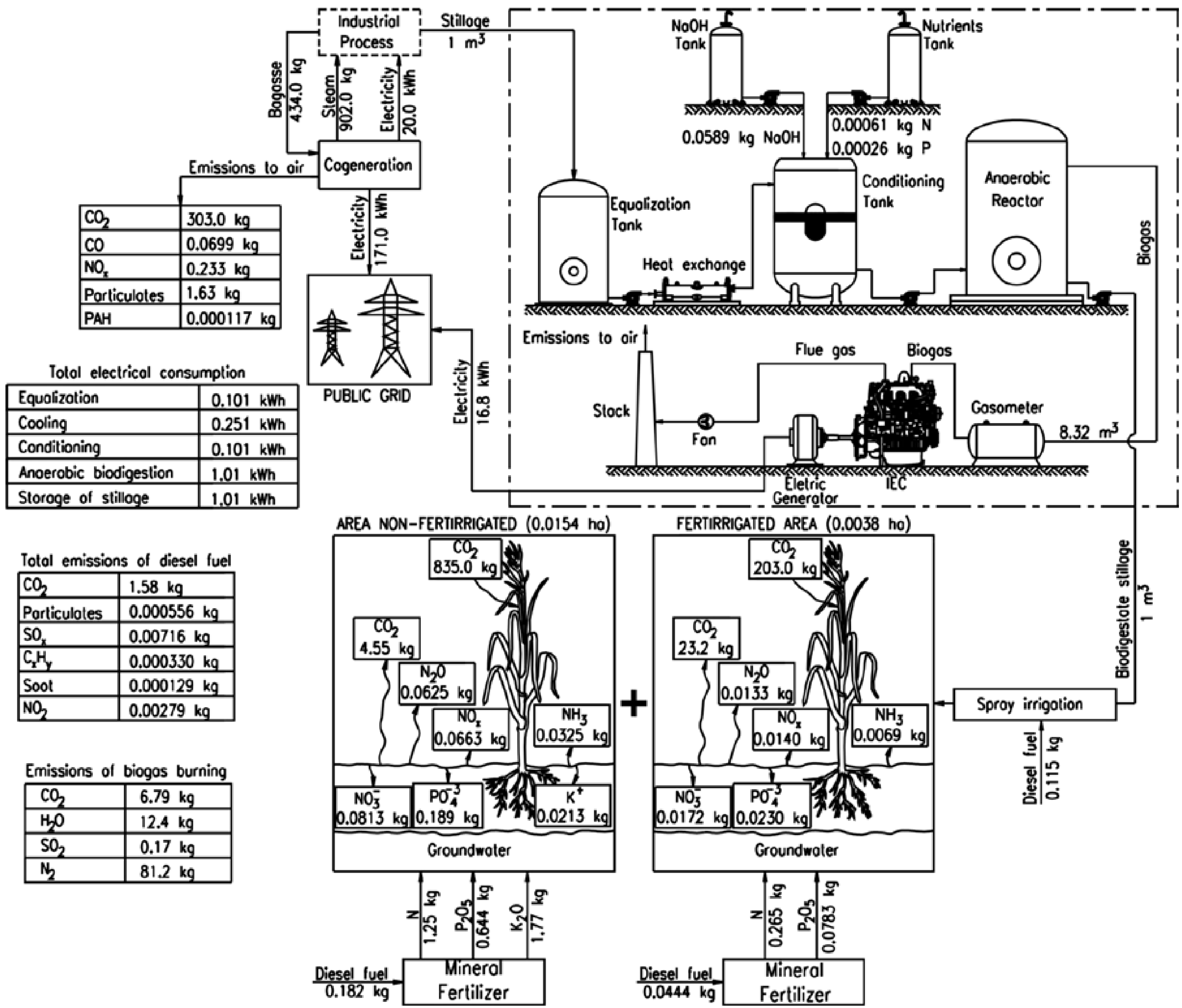
This work shows the results of the application of the LCA methodology for the analysis and comparison of four alternatives for stillage treatment and disposal: conventional "*in natura*" fertirrigation, anaerobic digestion, concentration until 40% for fertirrigation and concentration until 65% for combustion in boilers using fuel oil as supplementary fuel. The milling capacity of 1.99 million tonnes of sugarcane per crop, producing 154,000 tonnes of sugar and 81,000 m^3 of ethanol. The mill is located near the city of Sertãozinho, Brazil and local soil characteristics were also considered. The Simapro software and the CML 2 baseline 2000 are used as support tools. Conventional and concentrated stillage fertirrigation alternatives have the best environmental performance. In the combustion of stillage, we considered the installation of pollution control devices for SO_x and NO_x with 95% efficiency. From the point of view of climate change, based on the life cycle greenhouse gases balance, the best alternative was anaerobic digestion.

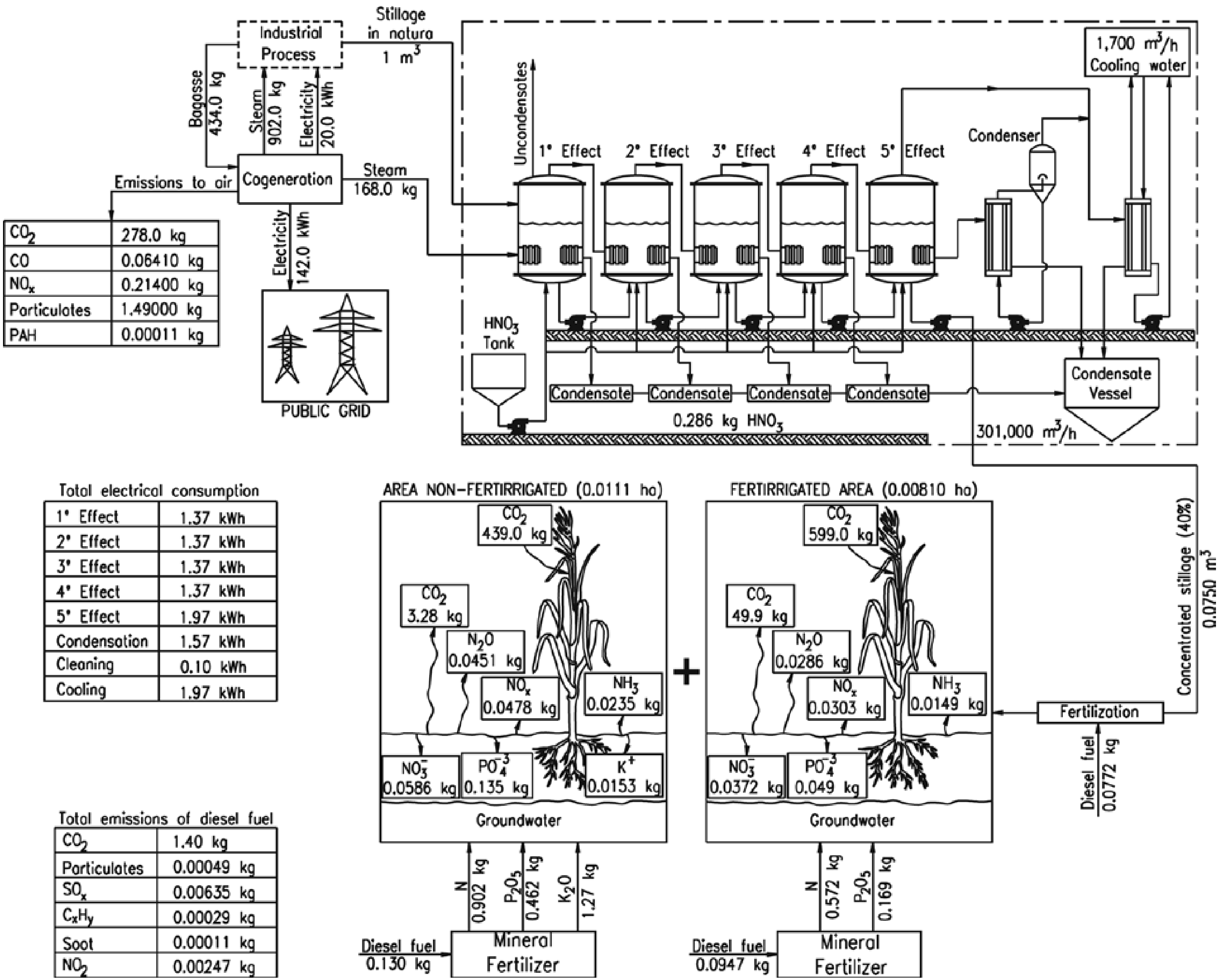
Scheme of the Fertirrigation Scenario



Scheme of the Anaerobic Digestion Scenario



Scheme of the Concentration up to 40% Scenario



CO_2	278.0 kg
CO	0.06410 kg
NO_x	0.21400 kg
Particulates	1.49000 kg
PAH	0.00011 kg

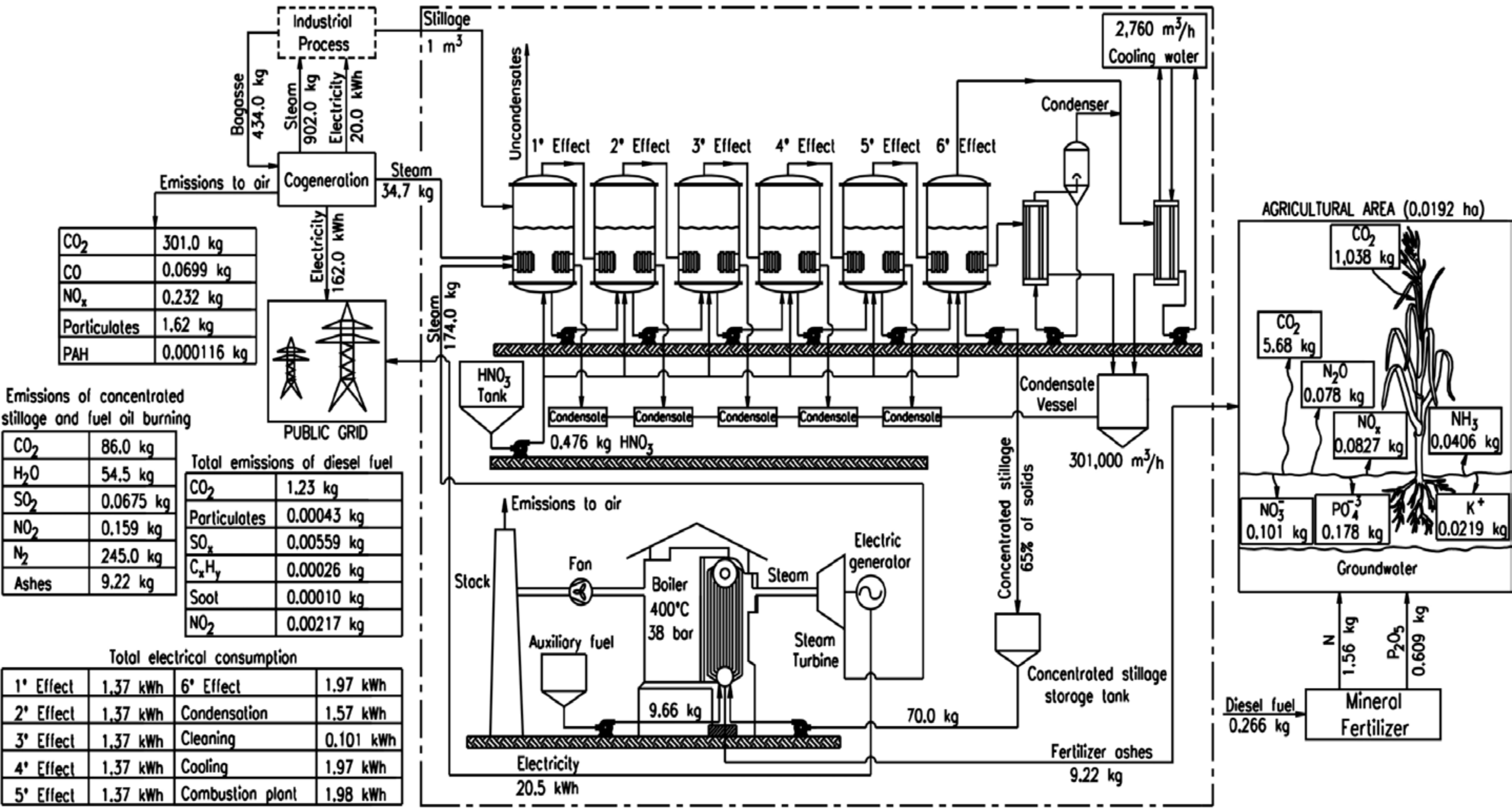
Total electrical consumption

1° Effect	1.37 kWh
2° Effect	1.37 kWh
3° Effect	1.37 kWh
4° Effect	1.37 kWh
5° Effect	1.97 kWh
Condensation	1.57 kWh
Cleaning	0.10 kWh
Cooling	1.97 kWh

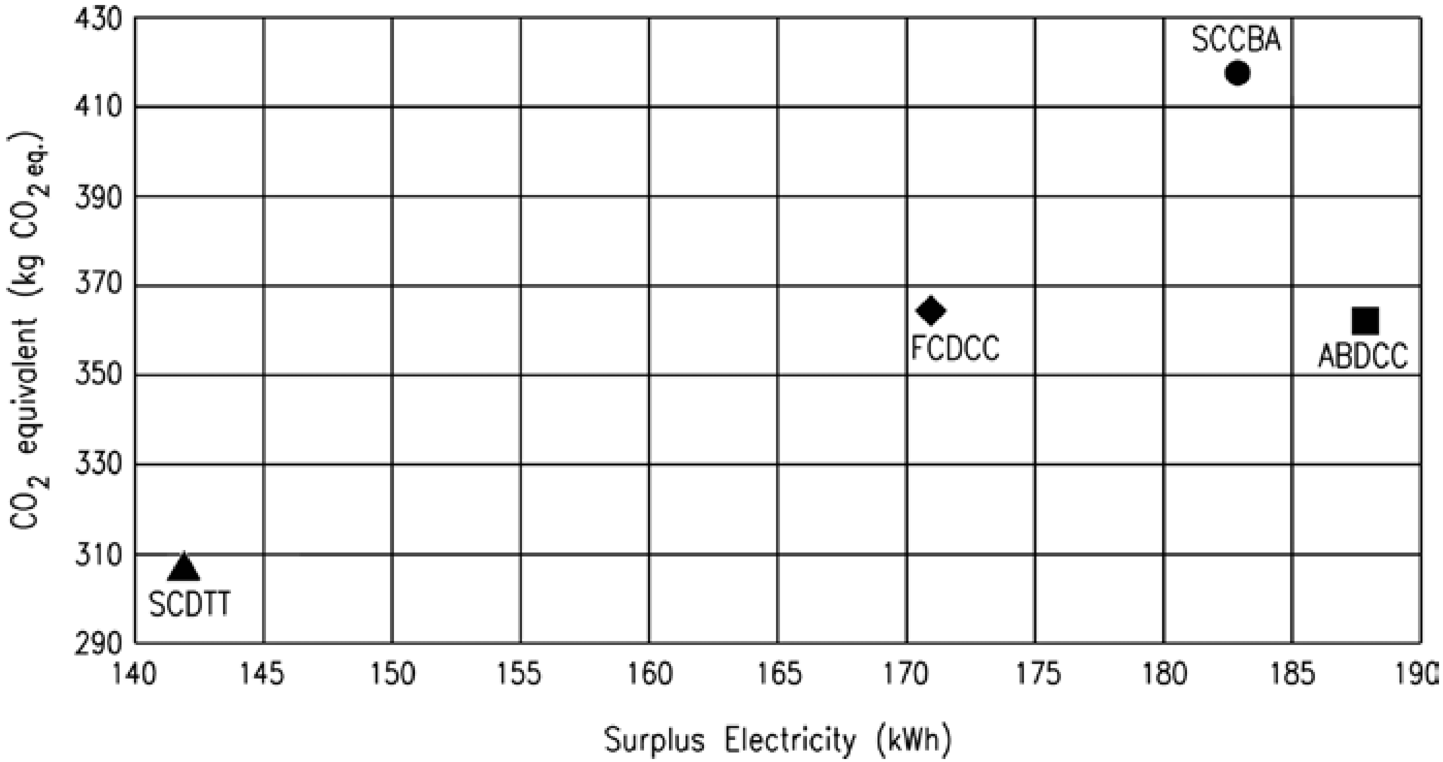
Total emissions of diesel fuel

CO_2	1.40 kg
Particulates	0.00049 kg
SO_x	0.00635 kg
C_xH_y	0.00029 kg
Soot	0.00011 kg
NO_2	0.00247 kg

Scheme of the Concentration up to 65% and Combustion With Auxiliary Fuel Scenario



Rate of emission of CO_2–equivalent in function of the electricity exported for the public grid



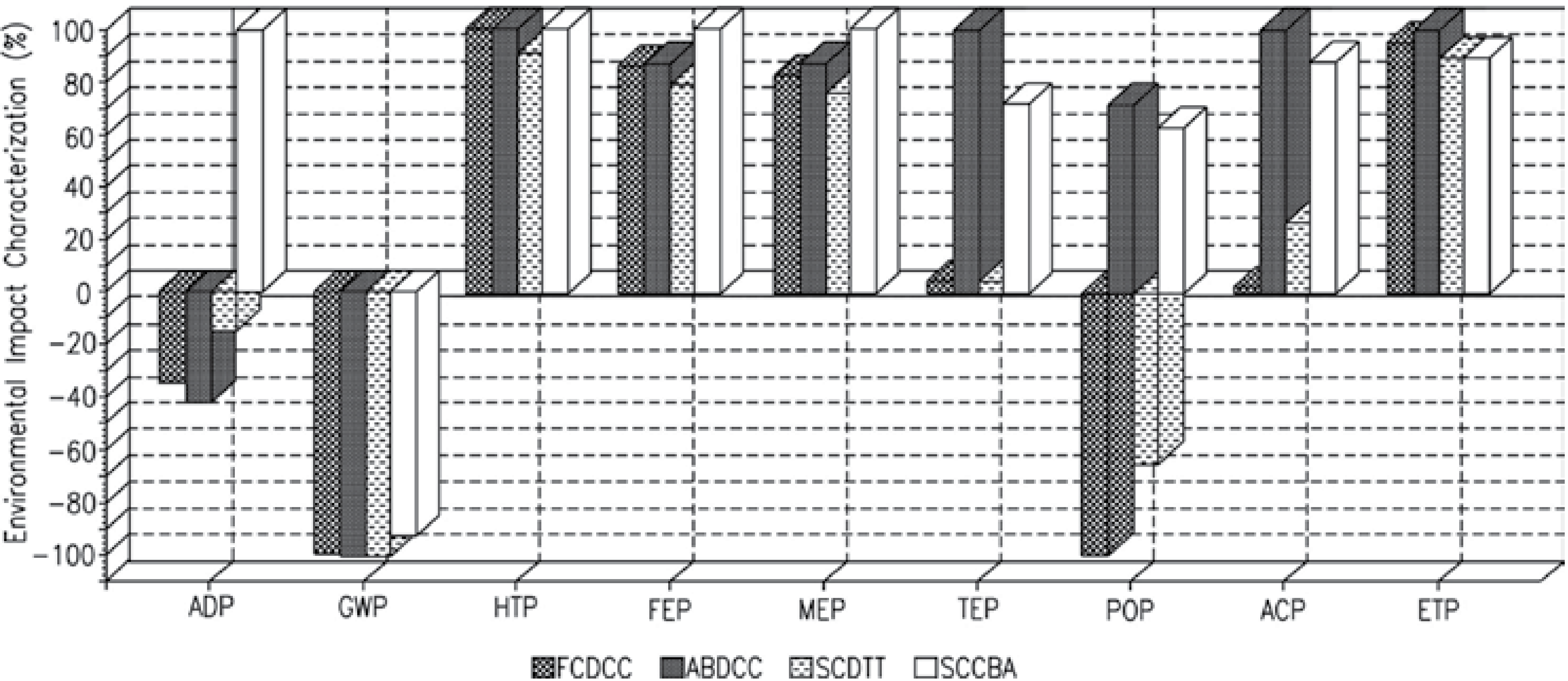
Energy Balance of Evaluated Stillage Disposal Scenarios

Scenario	Renewable energy output (MJ/m³ stillage)	Fossil fuel energy input (MJ/m³ stillage)	ER
FCDCC	118.45	2477.36	20.9
ABDCC	133.17	2538.56	19.1
SCDTT	152.56	2372.96	15.6
SCCBA	544.16	2564.36	4.7

Characterization of the Environmental Impacts of the Considered Scenarios

Impacts categories	Unit	FCDCC	ABDCC	SCDTT	SCCBA
ADP	kg Sb eq.	–0.0455	–0.0551	–0.0171	0.1430
GWP	kg CO_2 eq.	–698.0	–703.0	–749.0	–648.0
ODP	kg CFC-11 eq.	0	0	0	0
HTP	kg 1,4-DB eq.	66.9	66.9	61.3	66.7
FEP	kg 1,4-DB eq.	0.0203	0.0204	0.0185	0.0234
MEP	kg 1,4-DB eq.	36.0	38.1	33.1	43.2
TEP	kg 1,4-DB eq.	0.00031	0.00523	0.00027	0.00373
POP	kg C_2H_2	–0.00419	0.00337	–0.00264	0.00283
ACP	kg SO_2 eq.	0.0103	0.1950	0.0556	0.1670
ETP	kg PO_4^{-3} eq.	0.6430	0.6700	0.5970	0.5940

Percentile Comparison of the Contribution of Each Evaluated Scenario in Each Impact Category



Conclusions

- The world population, requirements for food and feed permanently increases. This creates growing demands for production and consumption of biofuels in the last years. While high oil prices favored this growth, it was also supported and drove by policies such as mandates, targets and subsidies catering to energy security and climate change considerations.

- To evaluate the biofuels sustainability it must be done serious, multidirectional and holistic evaluation and comparison of the environmental life cycle impacts, complemented with an energy balance of biofuels.

- It must be identified the intensity and interrelations of aggressions, the environment has suffered several detrimental effects, as a consequence of the production of biofuels. The results are a useful reference for future scientific works related to the development of new technologies and/or an effective adequateness of the existing ones, for the production of biofuels, with higher efficiency, effectiveness and safety, looking for a true sustainability.

- The role of the transportation of the crops, from the field to the factory, in the total environmental impact, making the distance a limiting factor and showing clearly the need to give priority to the development of ways and means to reduce it.

Conclusions

- In the cradle-to-gate LCA it is observed that the consumption of fossil fuels is associated with several impacts, such as, Abiotic Depletion and Global Warming Potential that indicates the necessity to reduce it in logistic and industrial stages, adopting other alternatives.

- The use of the co-products and residues of the production of the biofuels, for electrical and thermal energy, through cogeneration, to be used in the processes, improve the ecological and economic benefits, increasing the appeal of biofuels. The use of co-products in process, to generate steam and electricity, results in good indicators because it decreases or cancels the external dependence of fossil fuels and electricity, and allows the supply of renewable electricity or fuels to use in other process. This practice could, in some cases, represent the satisfaction of 85 to 95% of the total energy demand.

- A wide range of high added value products such as enzymes, organic acids, biopolymers, electricity, and molecules for food and pharmaceutical industries could be obtained upgrading of industrial co-products of biofuels production **(BIOREFINERIES).** Further works are required to have a more realistic consideration of the co-products and biomass valorization contribution to LCA indicators. The LHV approach for co-products has been used in real industrial applications process on animal feed and surplus electricity generation.


Thank you very much for your attention!
Itajubá/MG between the mountains
MSc. Mateus Henrique Rocha
mateus0@yahoo.com.br
The Aristotelian holistic principle: “The whole is grater that the addition of its parts”