Pyroliq 2019: Pyrolysis and Liquefaction of Biomass and Wastes

Proceedings

6-19-2019

Environmental assessment of pyrolysis in biorefineries based on palm oil wastes

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Environmental assessment of pyrolysis in biorefineries based on palm oil biomass wastes

York Castillo Santiago[a], Eric Alberto Ocampo Batlle[a], José Carlos Escobar Palacio[a], Osvaldo José Venturini[a], Electo Eduardo Silva Lora[a], Diego Mauricio Yepes Maya[a], Alberto Ricardo Albis Arrieta[b]

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Main issues

1. Introduction: Itajubá, UNIFEI and our work in pyrolysis.

2- Biorefineries in Palm Oil and Sugar Cane industries.

2. LCA of a Palm Oil biorefinery including biomass wastes pyrolysis: Materials and methods.

3. Results and discussion

4. Conclusions

1 Introduction

Itajubá, UNIFEI, NEST and Energy

ITAJUBÁ – University city in the South of Minas Gerais State
BRAZIL

96523 inhabitants

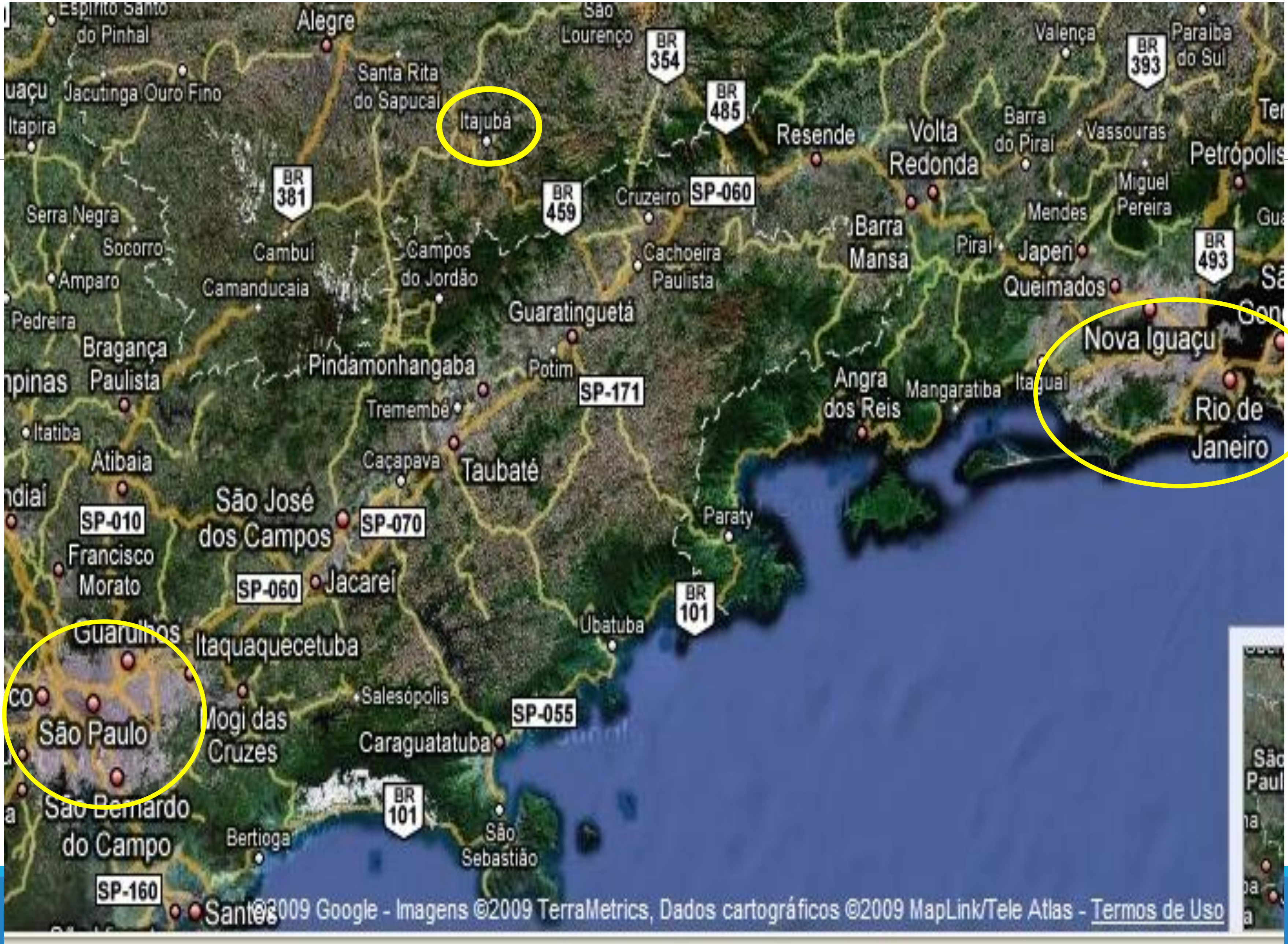
UNIVERSIDAD FEDERAL de ITAJUBÁ

UNIFEI

A technological university

1913

Itajubá city location in Brazil



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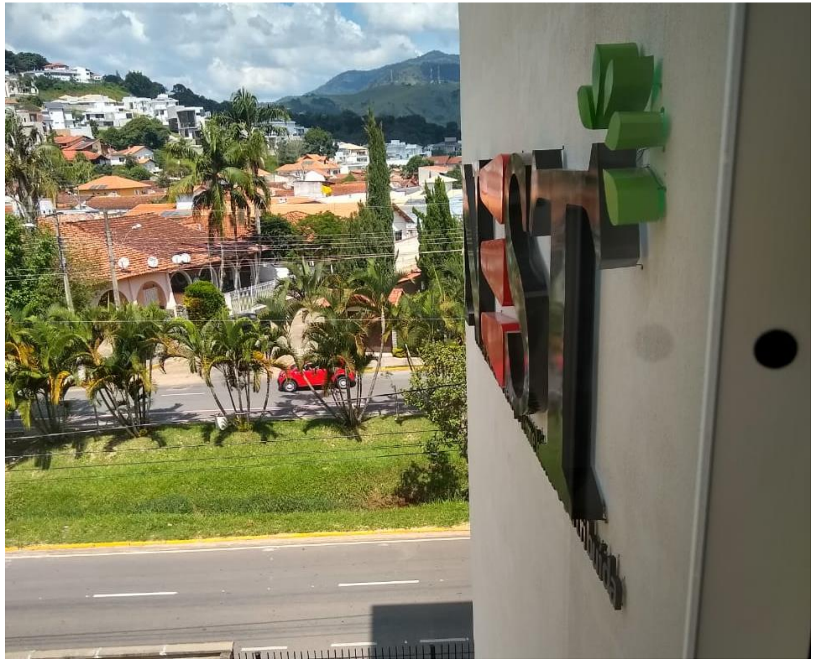
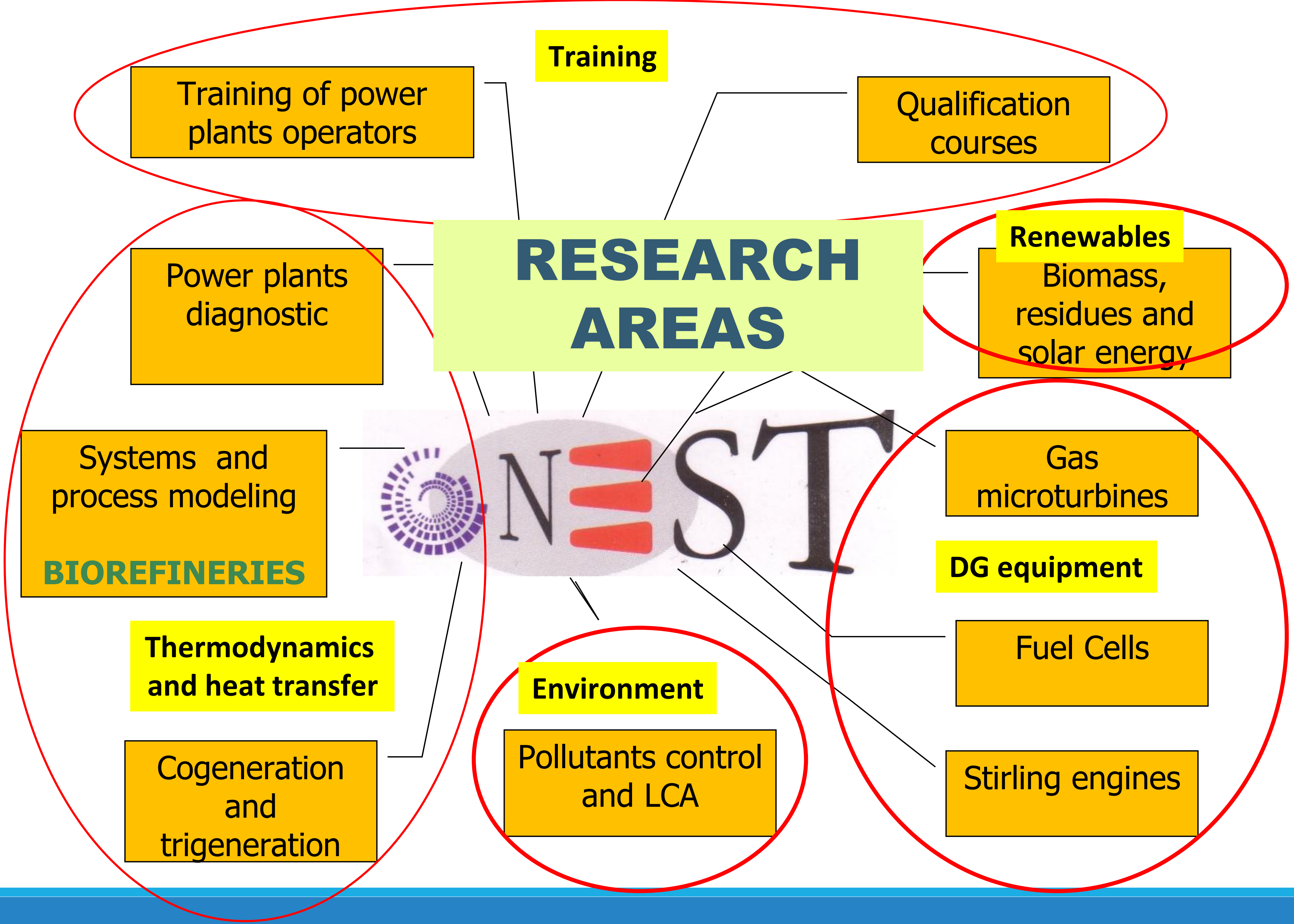
UNIFEI
Universidade Federal de Itajubá

RESEARCH GROUP NEST
FEDERAL UNIVERSITY OF ITAJUBÀ - BRAZIL



RESEARCH AREAS



Training

Training of power plants operators

Qualification courses

Renewables

Biomass, residues and solar energy

DG equipment

Gas microturbines

Fuel Cells

Stirling engines

Environment

Pollutants control and LCA

Thermodynamics and heat transfer

Power plants diagnostic

Systems and process modeling

BIOREFINERIES

Cogeneration and trigeneration

NEST Team - Professors

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
Marcelo José Pirani

Professor
Dr Rubenildo Vieira Andrade

Professor
DrJosé Carlos Escobar Palacio

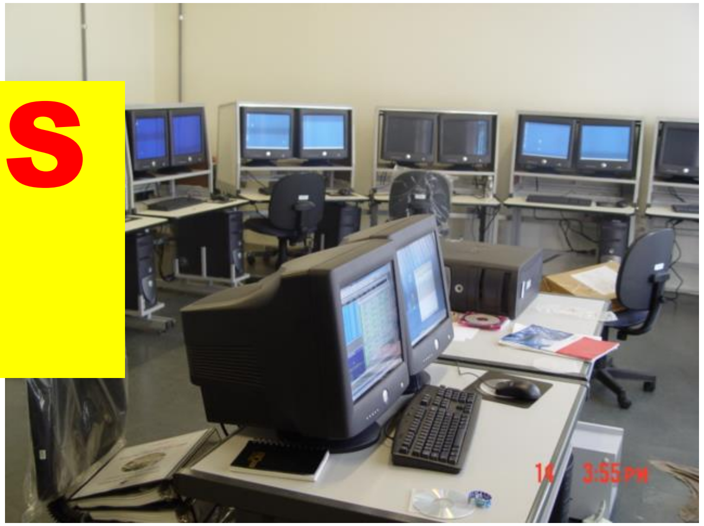
Professor
Dr. Diego Yepes Maya

++++ PhD and Master degree students

Ph.D - 13
Master Degree student -11

LABORATORIES
NEST/UNIFEI

Bubbling bed gasifier



Traning center for power plants operators

Biomass combustion laboratory

Gas microturbines and chiller

Fuel and gases characterization laboratory

Pilot Plant for RDFGasification

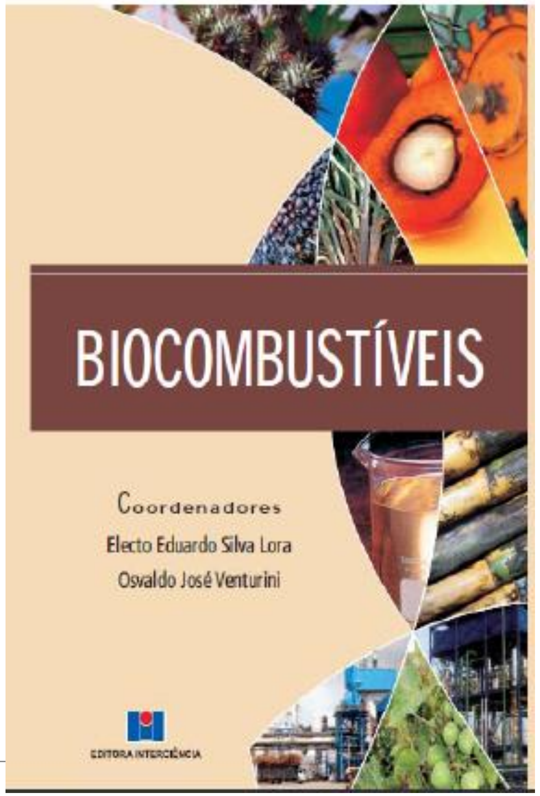
RDF briquettes production and gasification


LIPPEL

HELIOTHERMAL LAB

WHAT DO WE DO IN BIOMASS PYROLYSIS

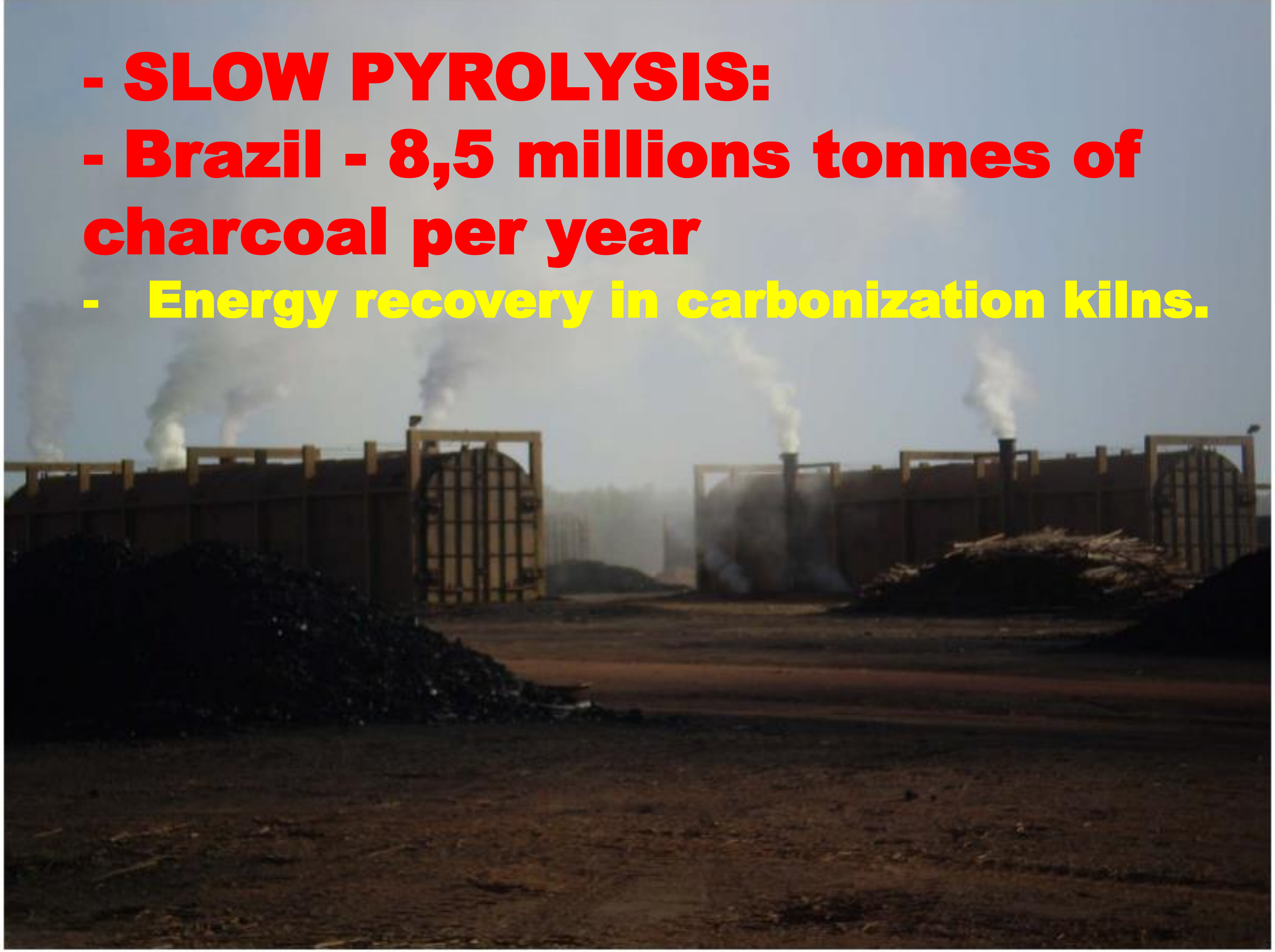
- Energy recovery in carbonization kilns.
- Evaluation of fast pyrolysis technology for biorefineries.
- Biovalue project (H2020). Bio-oil/char gasification.
- BRICs Project proposal. Biochar in agriculture.
- The second updated and reviewed edition of our book “Biocombustiveis” (BIOFUELS).
- A new discipline in graduate courses “Thermochemical conversion of biomass and wastes”.


BIOCOMBUSTÍVEIS

Coordenadores
Electo Eduardo Silva Lora
Osvaldo José Venturini

EDITORA INTERCIÊNCIA

BioValue



- SLOW PYROLYSIS:
- Brazil - 8,5 millions tonnes of charcoal per year
- Energy recovery in carbonization kilns.

BIOMASS AND BIOENERGY 69 (2014) 222–240

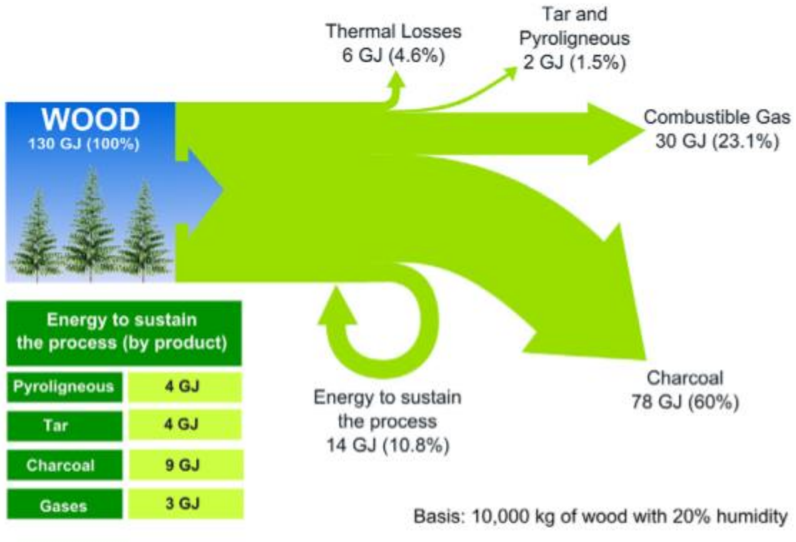
Available online at www.sciencedirect.com

ScienceDirect

http://www.elsevier.com/locate/biombioe

A new technology for the combined production of charcoal and electricity through cogeneration

Adriana de Oliveira Vilela [a,*,1], Electo Silva Lora [b],
Quelbis Roman Quintero [b], Ricardo Antônio Vicintin [a,1],
[a,1]



Basis: 10,000 kg of wood with 20% humidity

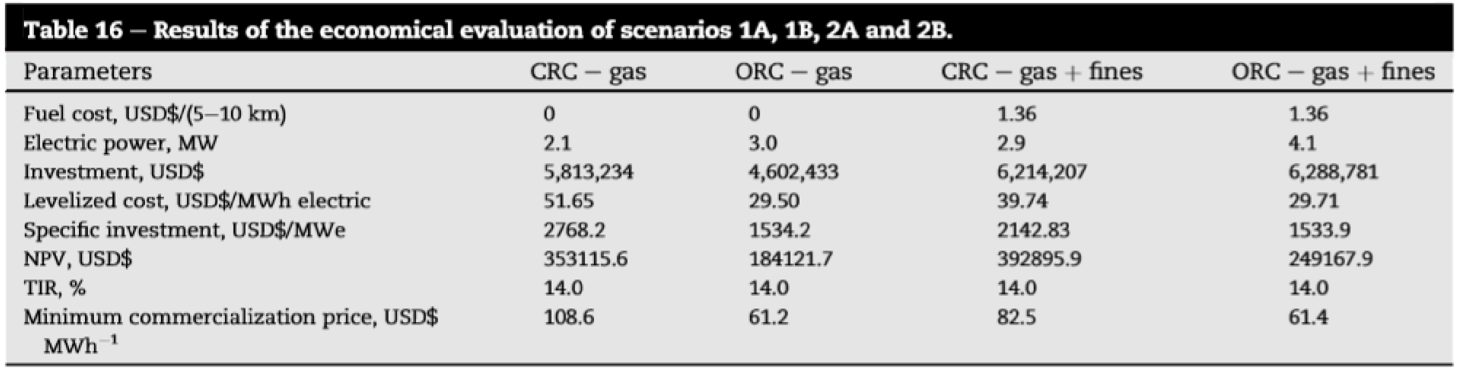
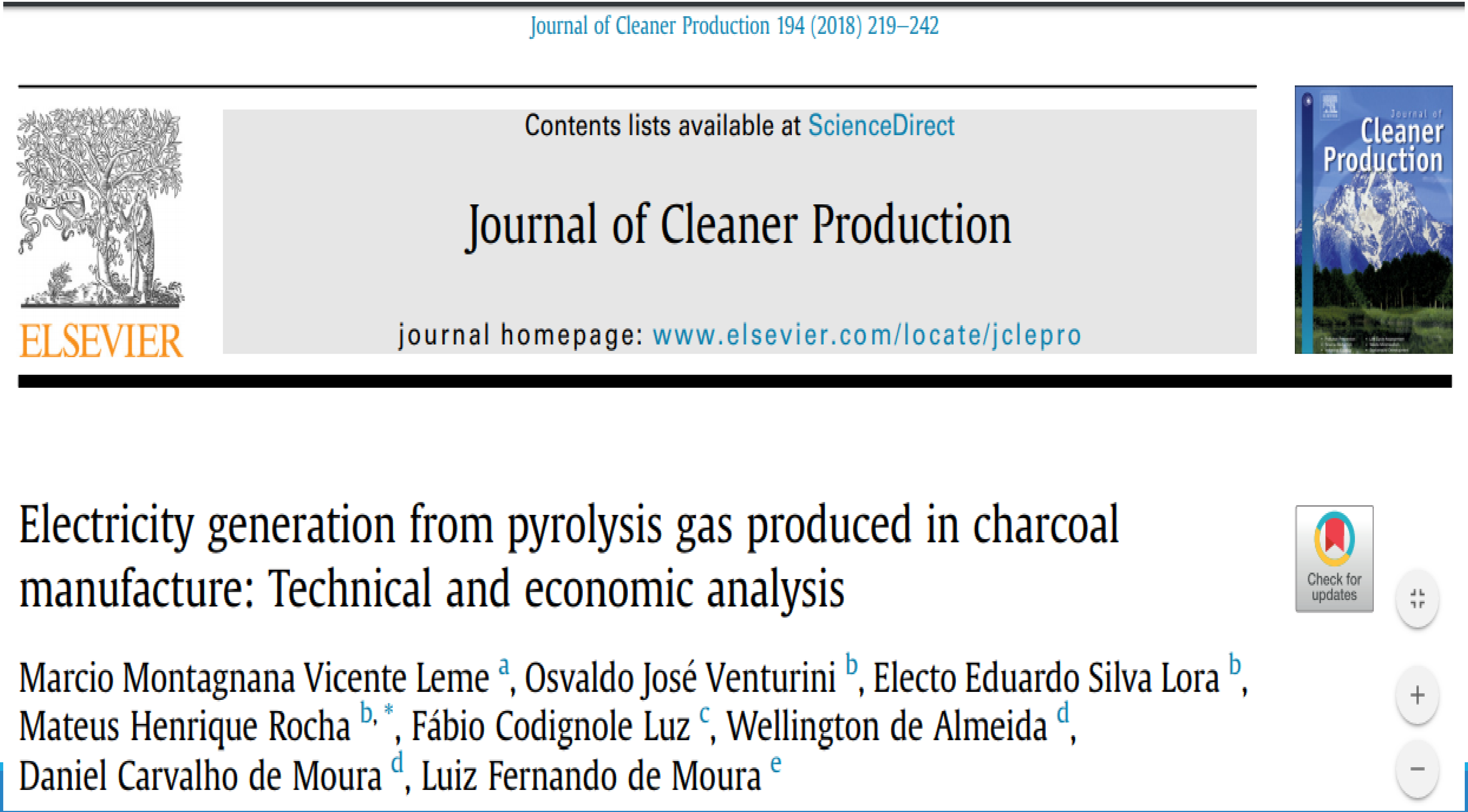


Table 16 – Results of the economical evaluation of scenarios 1A, 1B, 2A and 2B.

Parameters	CRC – gas	ORC – gas	CRC – gas + fines	ORC – gas + fines
Fuel cost, USD$/(5–10 km)	0	0	1.36	1.36
Electric power, MW	2.1	3.0	2.9	4.1
Investment, USD$	5,813,234	4,602,433	6,214,207	6,288,781
Levelized cost, USD$/MWh electric	51.65	29.50	39.74	29.71
Specific investment, USD$/MWe	2768.2	1534.2	2142.83	1533.9
NPV, USD$	353115.6	184121.7	392895.9	249167.9
TIR, %	14.0	14.0	14.0	14.0
Minimum commercialization price, USD$ MWh^{-1}	108.6	61.2	82.5	61.4



Journal of Cleaner Production 194 (2018) 219–242

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

Electricity generation from pyrolysis gas produced in charcoal manufacture: Technical and economic analysis

Marcio Montagnana Vicente Leme [a], Osvaldo José Venturini [b], Electo Eduardo Silva Lora [b],
Mateus Henrique Rocha [b, *], Fábio Codignole Luz [c], Wellington de Almeida [d],
Daniel Carvalho de Moura [d], Luiz Fernando de Moura [e]

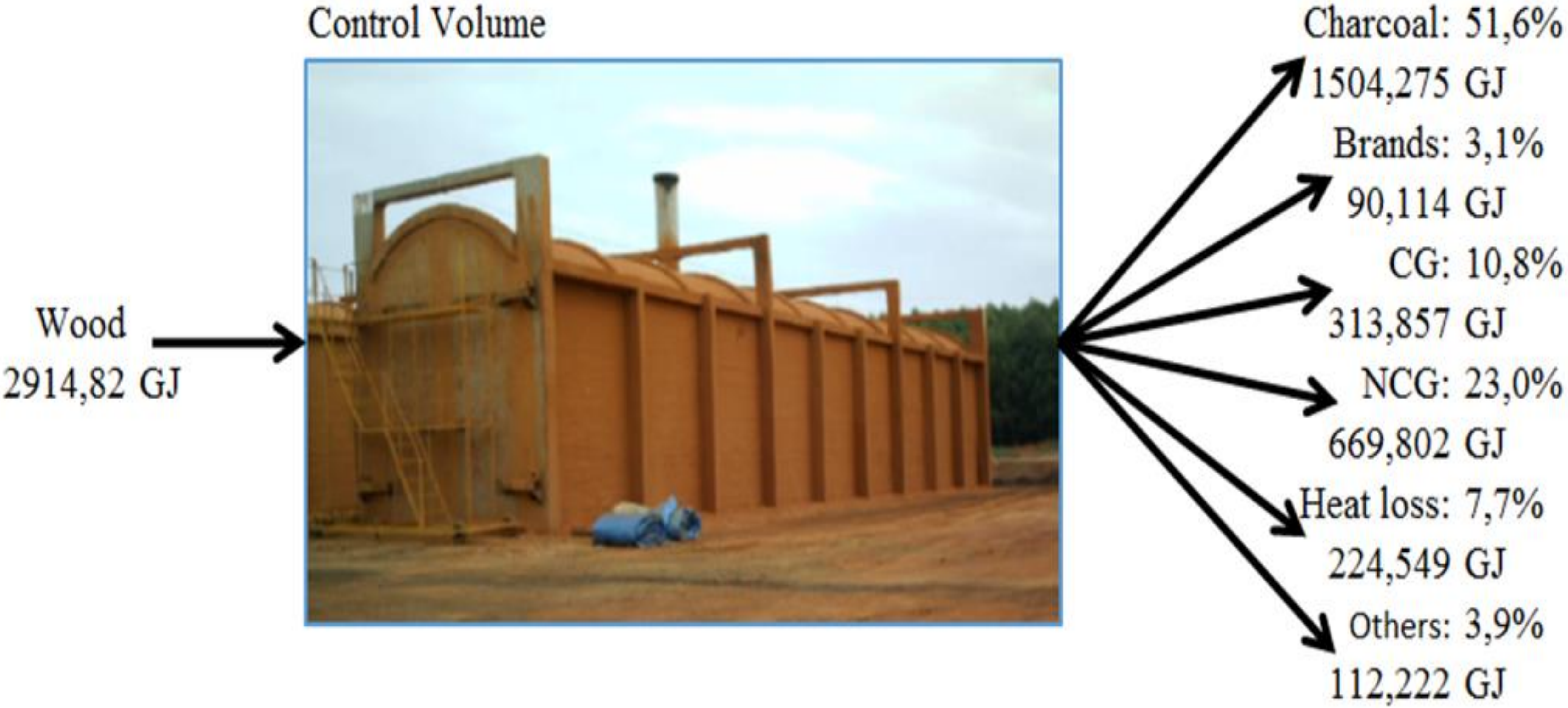


Figure 7. Results for the energy balance of wood carbonization in a rectangular kiln.

2 Biorefineries

LCA of Palm oil biorefinery concepts

WSU, PNNL, CENIPALMA, UNIFEI

Biomass and Bioenergy 95 (2016) 310–329

Contents lists available at ScienceDirect

Biomass and Bioenergy

journal homepage: http://www.elsevier.com/locate/biombioe

Research paper

Evaluation of alternatives for the evolution of palm oil mills into biorefineries

Jesus Alberto Garcia-Nunez [a, b], Deisy Tatiana Rodriguez [a], Carlos Andrés Fontanilla [a], Nidia Elizabeth Ramirez [a], Electo Eduardo Silva Lora [c], Craig Stuart Frear [b], Claudio Stockle [b], James Amonette [d], Manuel Garcia-Perez [b, *]

[a] *Colombian Oil Palm Research Centre, Cenipalma, Bogotá, Colombia*

[b] *Biological and Agricultural Engineering Department, Washington State University, Pullman, WA, USA*

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[d] *Pacific Northwest National Laboratory, PO Box 999, Richland, WA 99352, USA*

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Applied Energy xxx (xxxx) xxxx

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

Biorefineries productive alternatives optimization in the brazilian sugar and alcohol industry

Juarez Corrêa Furtado Júnior[a,b,*], José Carlos Escobar Palacio[b,*], Rafael Coradi Leme[c,*], Electo Eduardo Silva Lora[b,*], José Eduardo Loureiro da Costa[b], Arnaldo Martín Martínez Reyes[b], Oscar Almazán del Olmo[d]

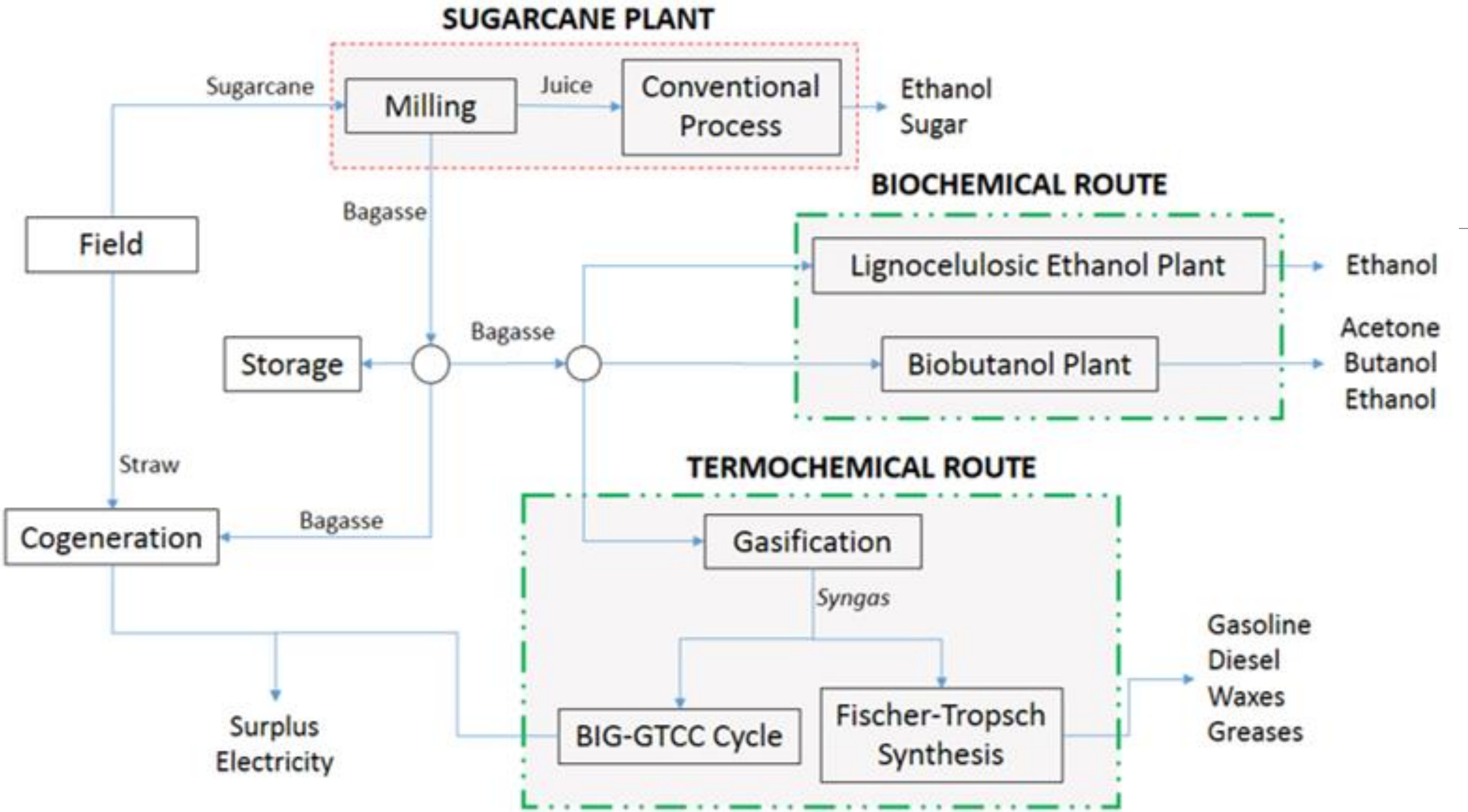


Figure 1: General scheme of the proposed biorefinery

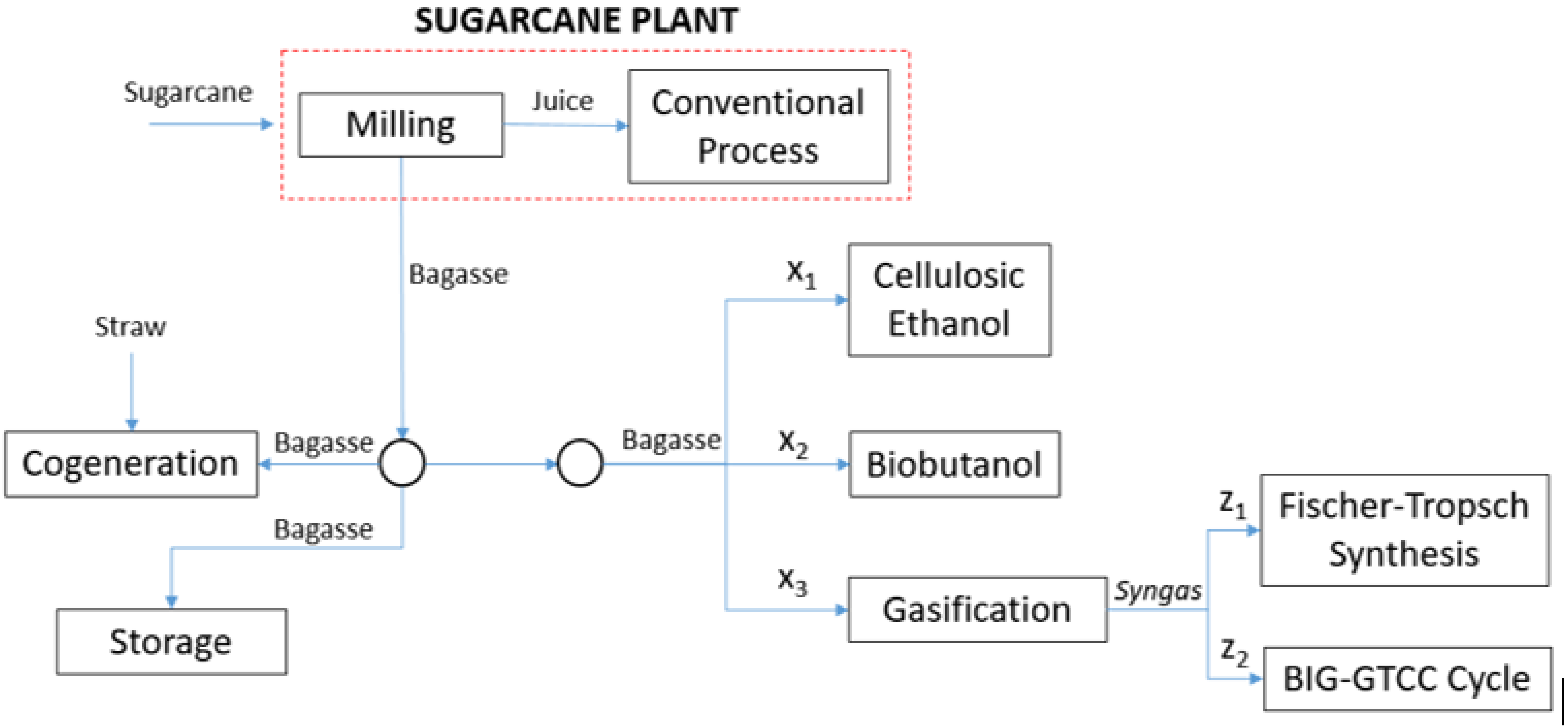
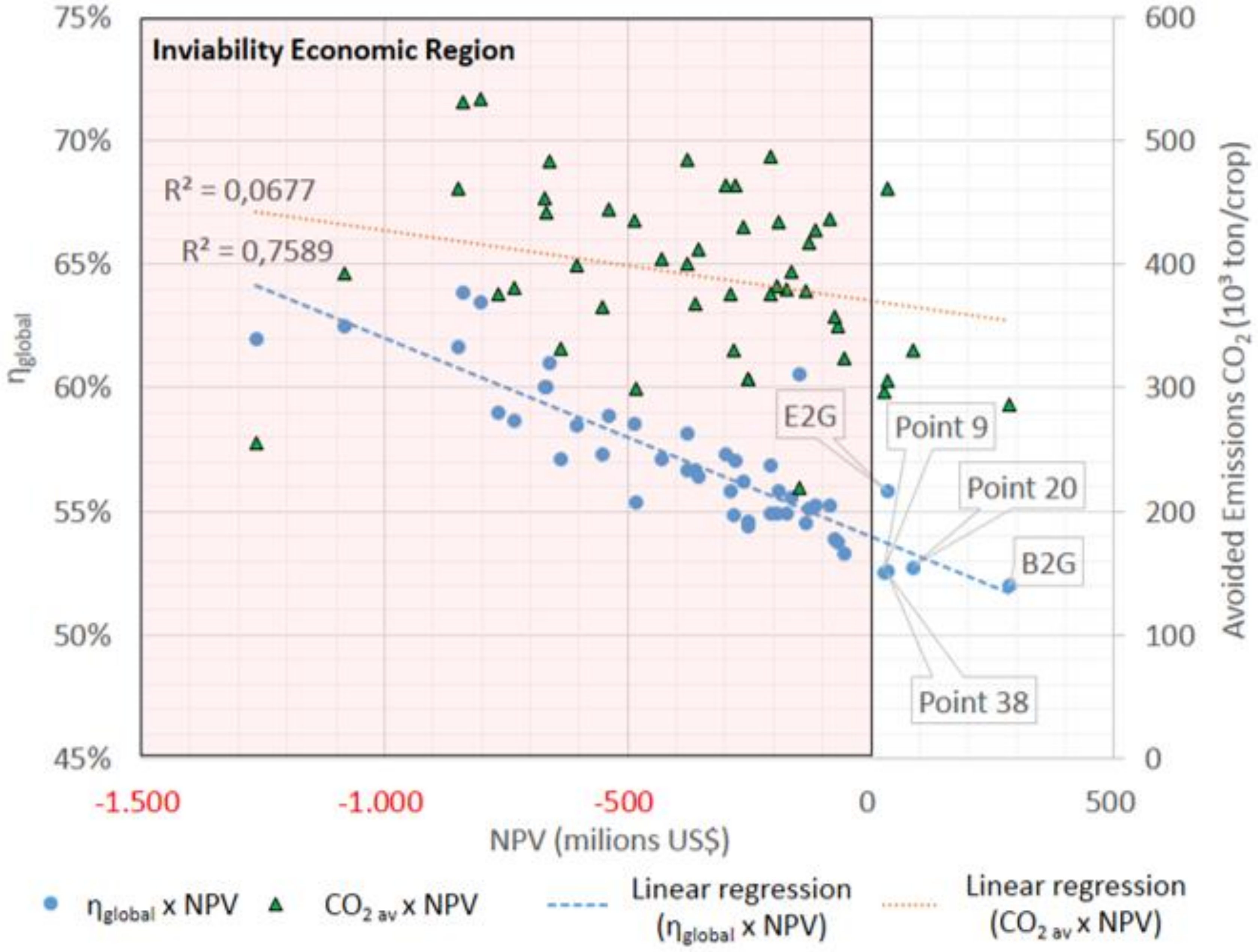


Figure 2: Scheme of allocation of biomass in biorrefinery.


Inviability Economic Region
R² = 0,0677
R² = 0,7589
E2G
Point 9
Point 20
B2G
Point 38
75%
70%
65%
60%
55%
50%
45%
ηglobal
600
500
400
300
200
100
0
Avoided Emissions CO2 (10³ ton/crop)
-1.500
-1.000
-500
0
500
NPV (milions US$)
ηglobal x NPV
CO2 av x NPV
Linear regression (ηglobal x NPV)
Linear regression (CO2 av x NPV)

INTEGRATED PALM OIL AND SUGAR MILLS BIOREFINERIES

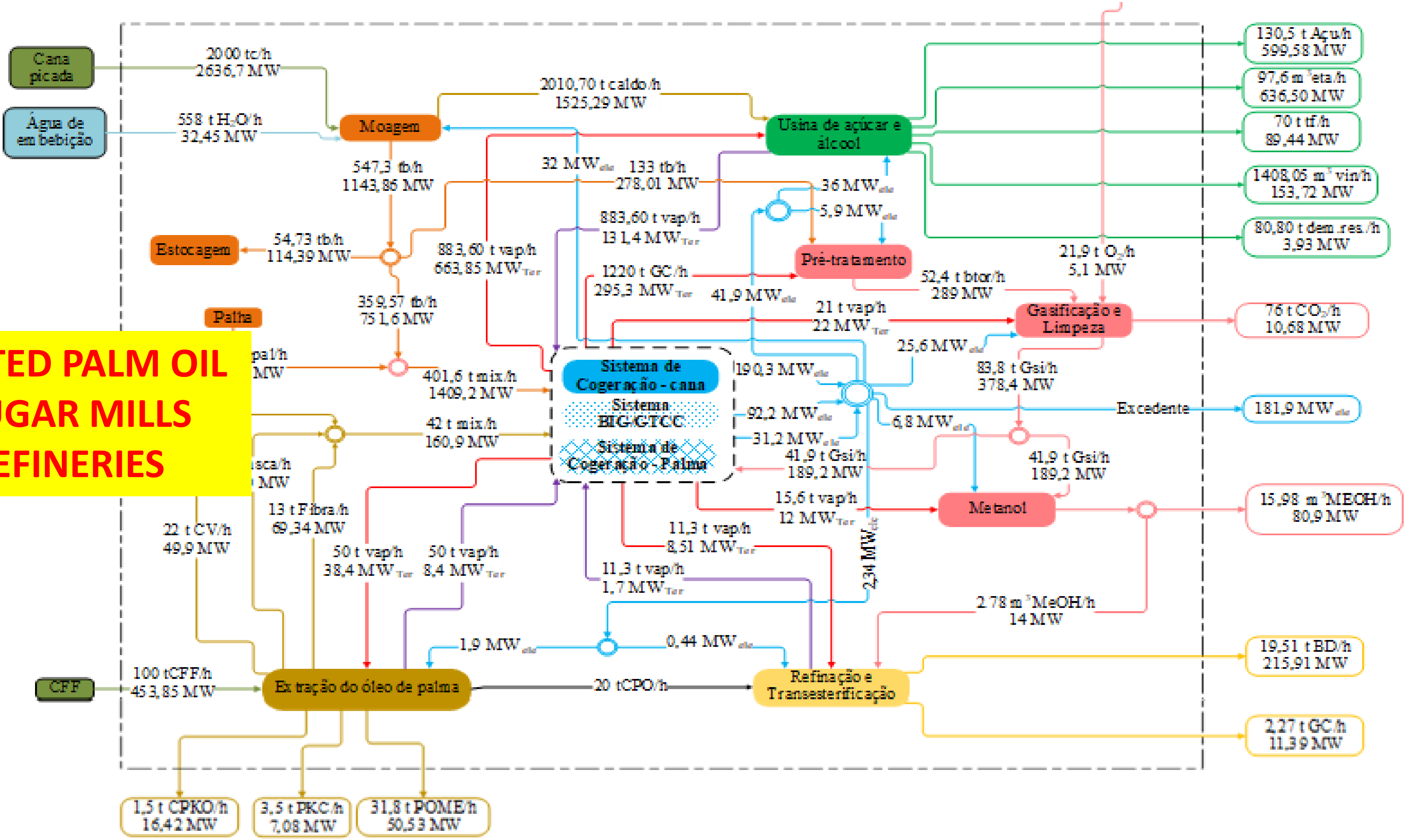


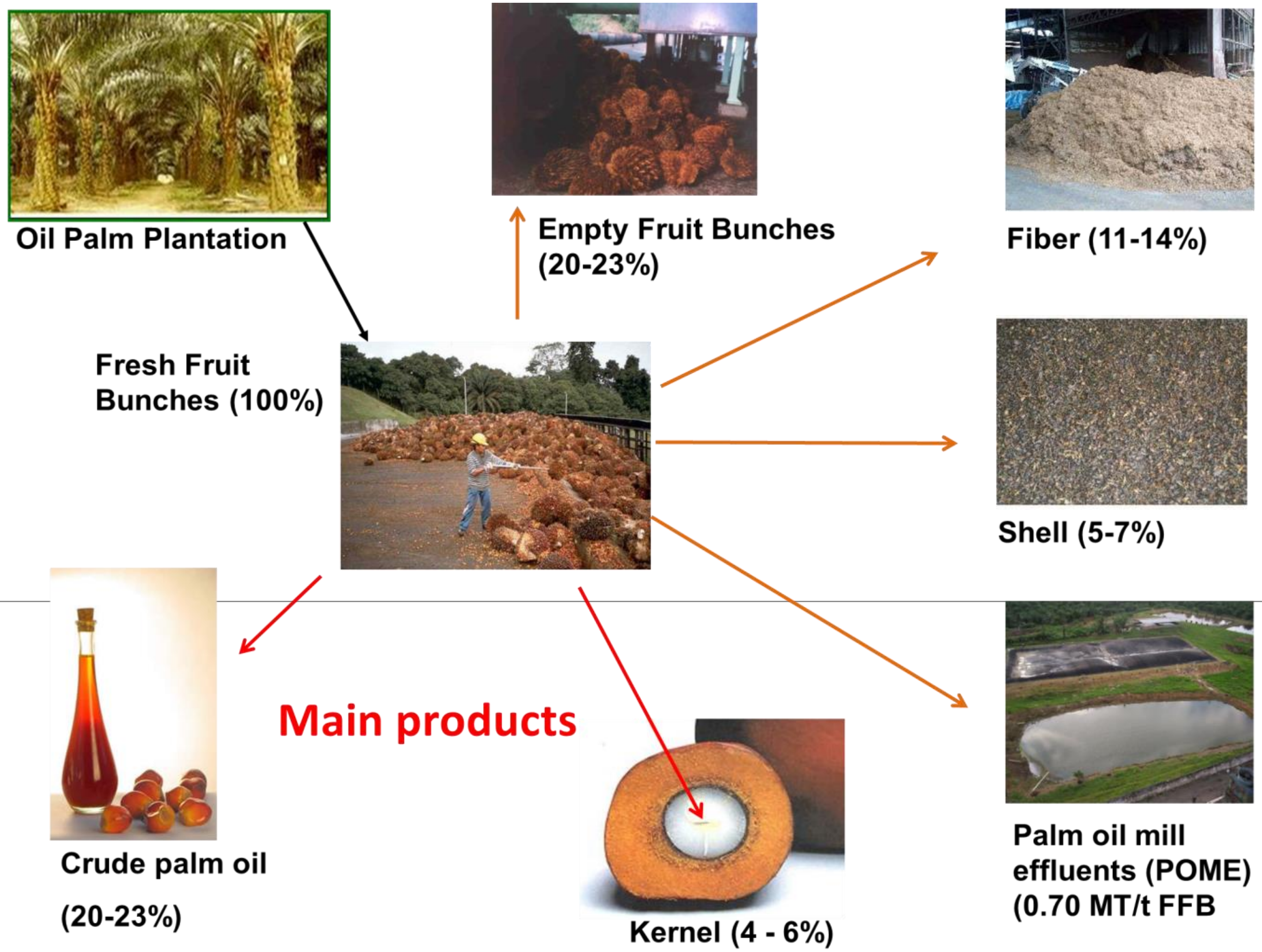
Figura 4.7: Balanço de massa e energia para o estudo de caso IV.

3 LCA of a Palm oil biorefinery

CRUDE PALM OIL

Crude Palm Oil (CPO) is obtained from palm fruit mesocarp (Elaeis guineensis).

Residual biomass - oil palm mill



Oil Palm Plantation

Empty Fruit Bunches (20-23%)

Fiber (11-14%)

Fresh Fruit Bunches (100%)

Shell (5-7%)

Main products

Crude palm oil

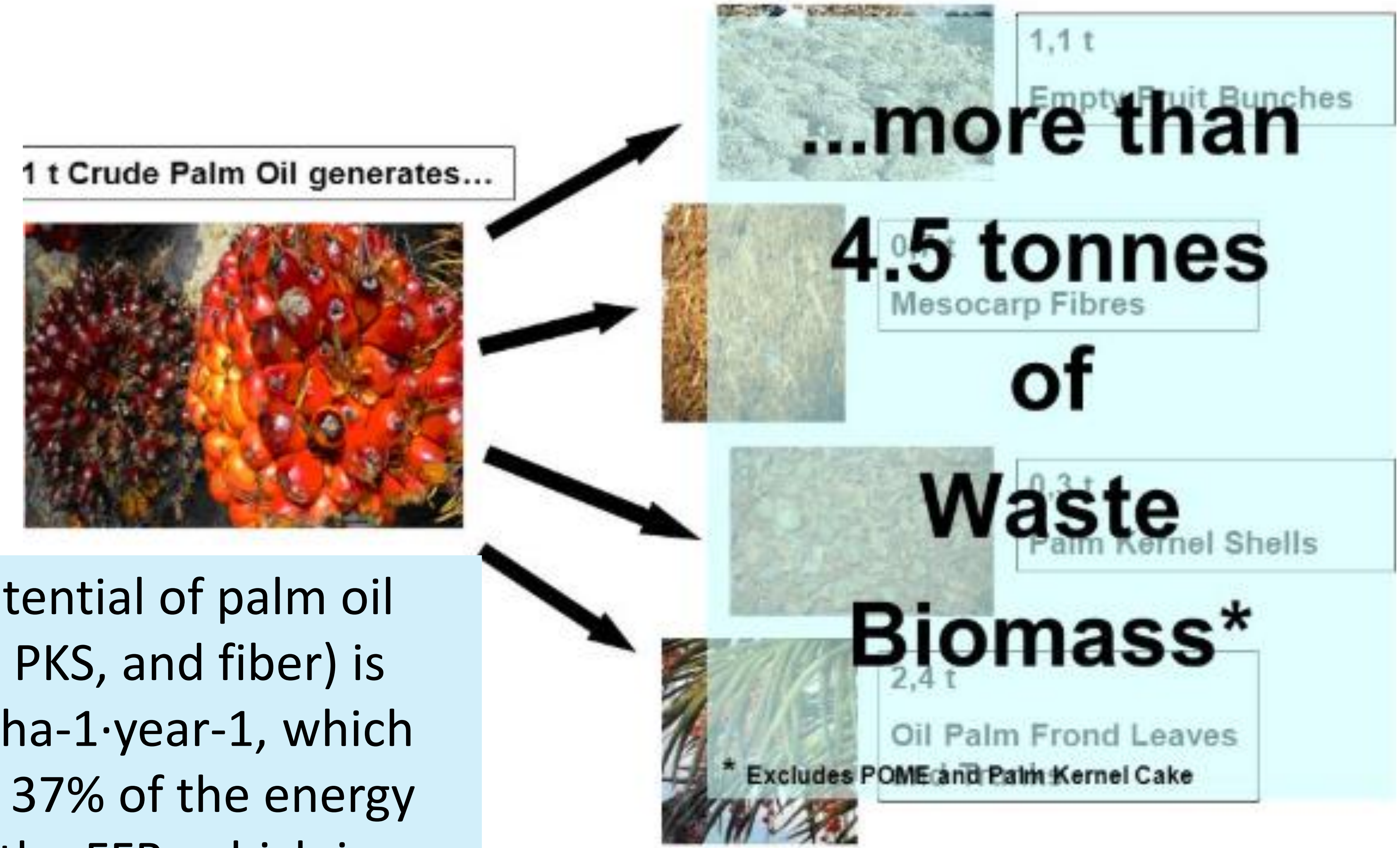
(20-23%)

Kernel (4 - 6%)

Palm oil mill effluents (POME) (0.70 MT/t FFB

García-Núñez et al, 2010

The total biomass obtained from the production process is 41.5% of each tonne of FFB

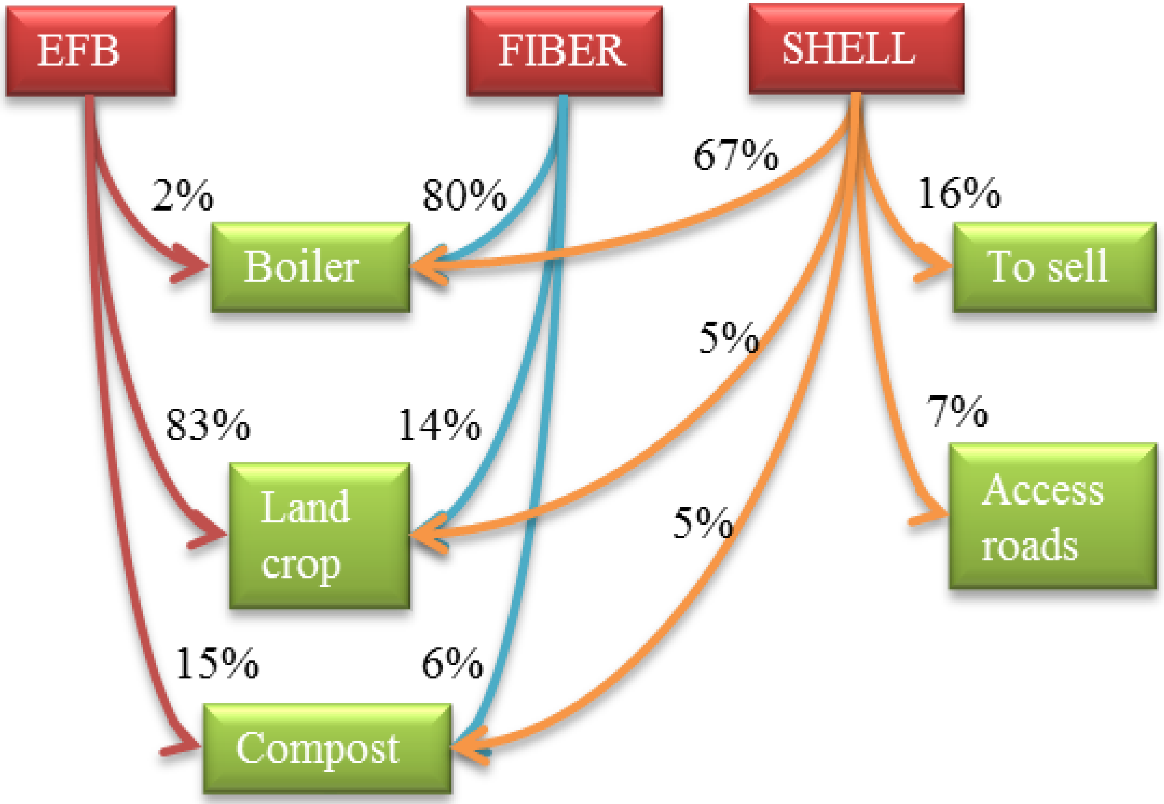


…more than 4.5 tonnes of Waste Biomass*

* Excludes POME and Palm Kernel Cake

The energy potential of palm oil biomass (EFB, PKS, and fiber) is around 100 GJ·ha-1·year-1, which corresponds to 37% of the energy contained in the FFB, which is approximately 270 GJ·ha-1·year-1.

Present use of biomass in palm oil mills



EFB
FIBER
SHELL
Boiler
Land crop
Compost
To sell
Access roads
2%
83%
15%
80%
14%
6%
67%
5%
5%
16%
7%

2018 estimates of biomass residues availability in palm oil mills worldwide

FFB: 350 millon tonnes

CPO: 70 million tonnes

The total biomass obtained from the production process is 41.5% of each tonne of FFB

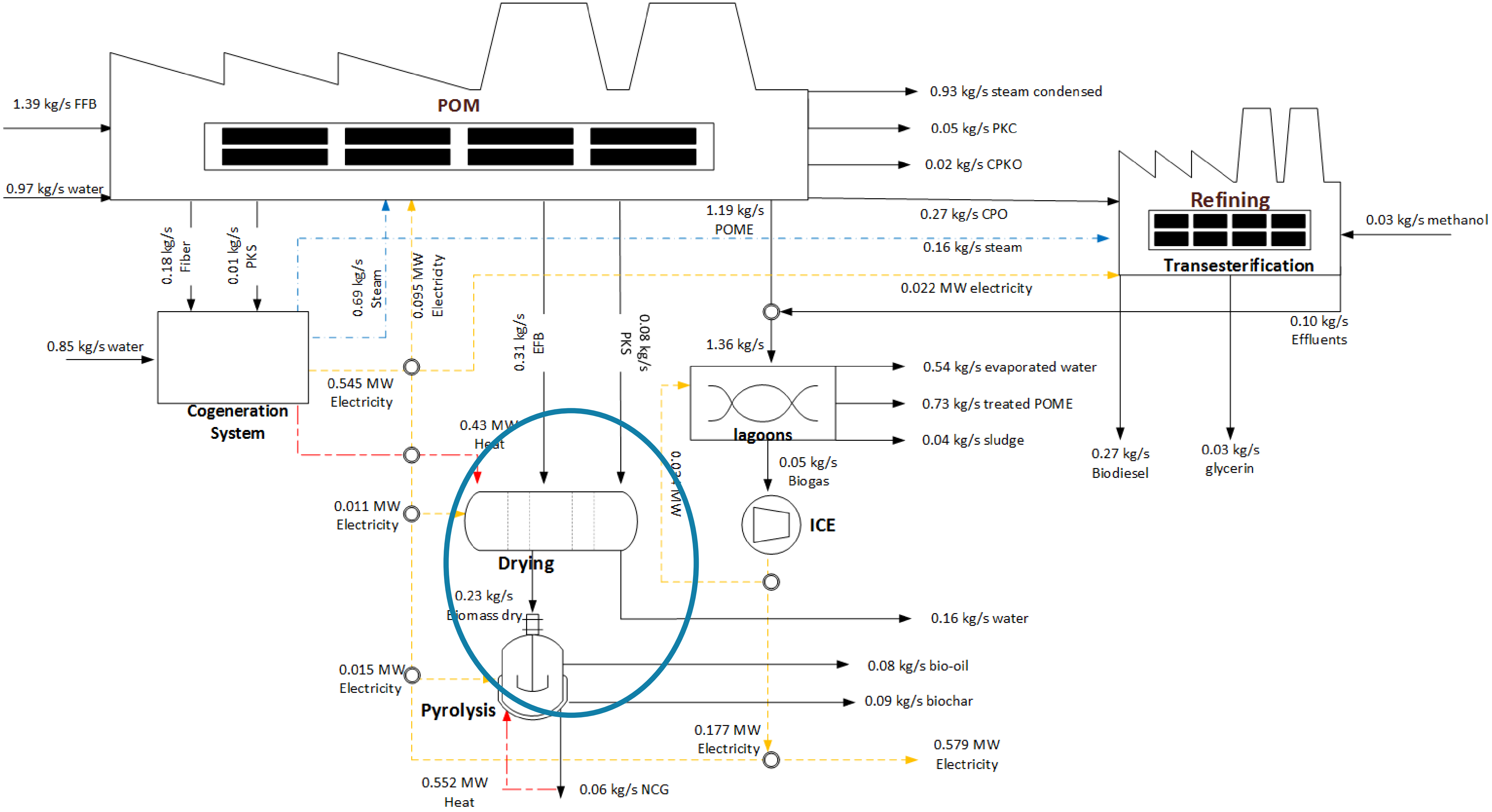
Biomass availability: 157 million tonnes

MAIN GOAL

In this work it was done an energy and environmental analysis of a scheme of polygeneration of the palm oil in a Brazilian POM, to determine and evaluate the benefits of the use of waste in which stands out the simultaneous obtaining of biodiesel, bio-oil and electricity; quantifying through the LCA the potential environmental impacts resulting from this diversification in the production of CPO.

- In this study, the method selected for the environmental impacts allocation among products and by-products was the energy-based allocation **(ATRIBUTIONAL LCA).** In the extraction stage, the allocation is distributed as follows: CPO (54.27%), CPKO (4.07%), Fiber (17.19%) PKS (10.34%), EFB (12.37%) and PKC (1.76%). In the case of the refining stage, it is 98.5% for refined palm oil and 1.5% for palm fatty acid distillation, in the transesterification stage it was 90% for biodiesel and 10% for glycerin, and for the fast pyrolysis stage, the distribution is 51% for bio-oil and 49% for biochar.

- **NEXT STEP IS TO USE A CONSEQUENTIAL (FRONTIERS EXPANSION LCA).**



Mass and energy balances of the biorefinery.

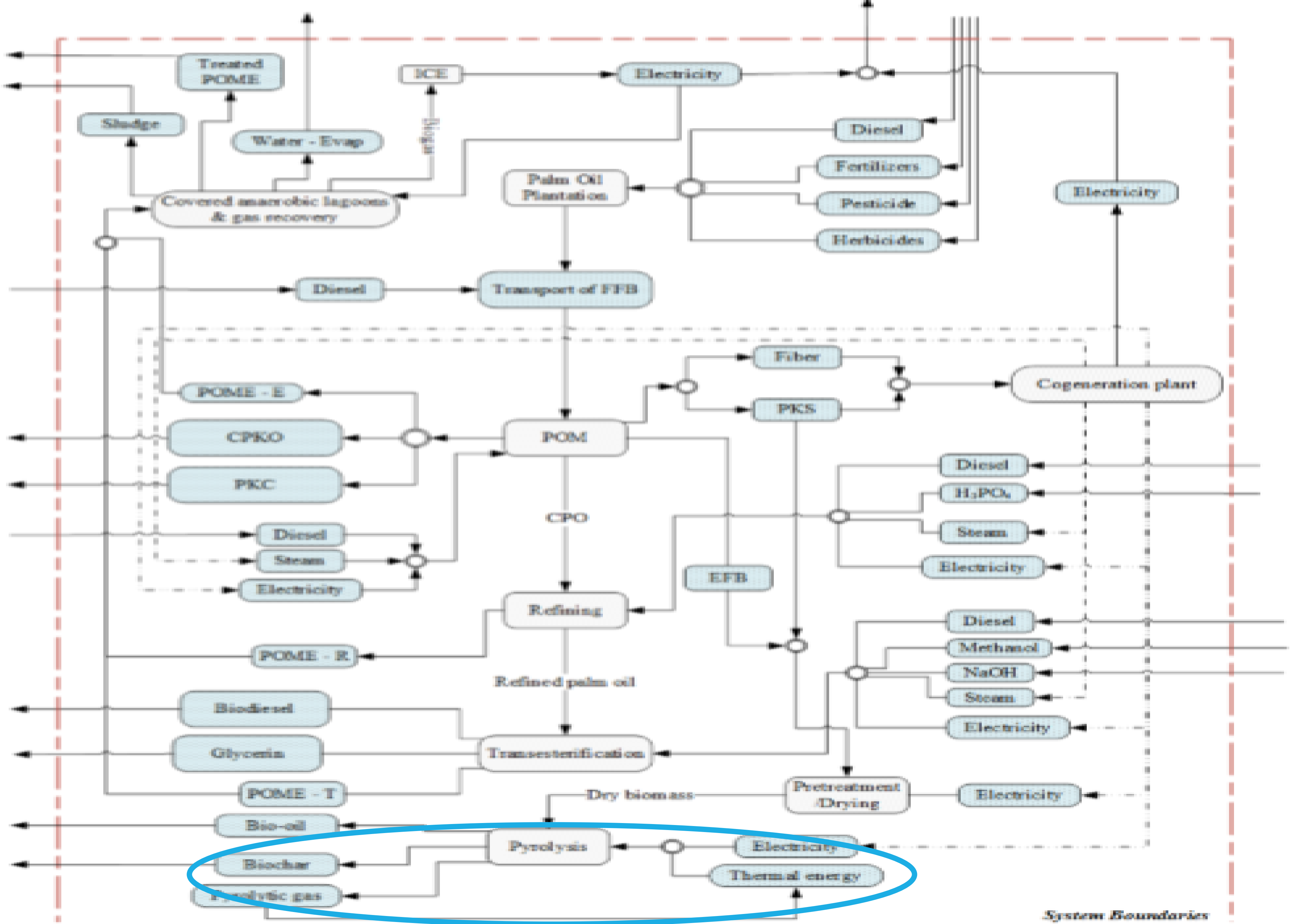


Figure 4.7: System boundaries of the analyzed products.

2. Materials and methods

A scenario of a POM with a production capacity of 1.39 kg/s of FFB was designed, containing a pyrolysis process and a refining/transesterification stage of the CPO for obtaining biodiesel and glycerin.

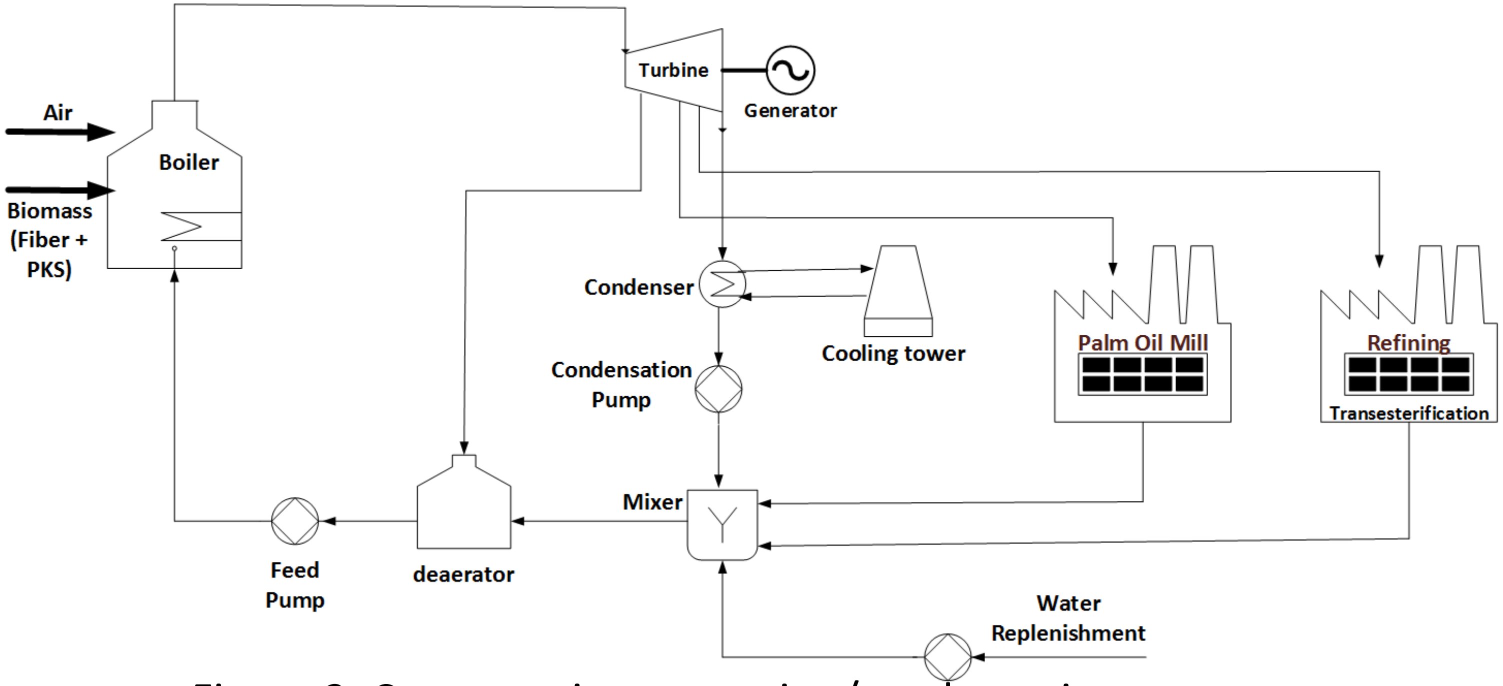


Figure 2. Cogeneration extraction/condensation system .

2. Materials and methods

The values adopted for the availability of CPO, EFB, PKS, POME, PKS, fiber, Palm Kernel Cake (PKC) and Crude Palm Kernel Oil (CPKO) are summarized in Table 1.

Table 1. Availability of products obtained in the POM

EFB availability (ton/ton FFB)	0.22
PKS availability [ton/ton FFB]	0.07
Fiber availability [ton/ton FFB]	0.13
PKC availability [ton/ton FFB]	0.035
POME availability [ton/ton FFB]	0.328
CPKO availability [ton/ton FFB]	0.017
CPO availability [ton/ton FFB]	0.02

2. Materials and methods

The values adopted for the pyrolysis and anaerobic digestion stage of the scenario are summarized in Table 2, while for cogeneration system, refining/transesterification, and drying stage in Table 3.

Table 2. Indicators for the pyrolysis and anaerobic digestion stage

Pyrolysis	
Electrical energy consumption [kWh/kg bio-oil]	0.05
Bio-oil ratio [kg/kg bio-oil]	1
Non-condensable Gases ratio [kg/kg bio-oil]	1.06
Biochar ratio [kg/kg bio-oil]	0.58
Anaerobic digestion	
Electrical energy consumption [kWh/ton de POME]	0.007
Efficiency ICE [%]	25
Biogas ratio [ton/ton de POME]	0.03
Sludge ratio [ton/ton de POME]	0.03

Table 3. Indicators for the cogeneration system, refining/transesterification, and drying stage

Cogeneration extraction/condensation system	
Isentropic efficiency of pumps [%]	85
Boiler efficiency [%]	80
Isentropic efficiency of the turbine [%]	70
Efficiency of the cogeneration cycle [%]	18.02
Pressure in the refining plant [bar]	2.5
Pressure in the extraction plant [bar]	4
Refining plant/transesterification	
Electrical energy consumption [kWh/ton CPO]	22
Steam consumption [kg/ton CPO]	564
Biodiesel ratio [kg/ton CPO]	975.5
Glycerin ratio [kg/ton CPO]	113.6
Effluents ratio [kg/ton CPO]	348
Drying	
Biomass inlet temperature [°C]	25
Biomass outlet temperature [°C]	110
Inlet temperature of exhaust gases [°C]	215
Outlet temperature of the exhaust gases [°C]	110
Moisture of biomass [%]	50
Electrical energy consumption [kWh/$\text{ton}_{\text{extracted water}}$]	19
Moisture of dry biomass [%]	15
Enthalpy of vaporization of water [kJ/kg]	2691.1

4 Results and discussion

4. Results and discussion

The mass and energy balances of the scenario are presented in Figure 3. The fiber is burned in the boiler of the cogeneration cycle to satisfy the consumption of electrical energy (0.095 MWh) and steam (0.69 kg steam/s) of the same POM. In the refining/transesterification stage are produced 0.27 kg/s of biodiesel and 0.03 kg/s of glycerin and the consumption of electrical energy for this stage are 0.022 MW. The bio-oil and biochar produced are 0.08 kg/s and 0.09 kg/s, respectively.

4. Results and discussion

Figure 5 shows that the production of bio-oil and biochar through fast pyrolysis does not have considerably environmental impacts (52 mPt), when compared to biodiesel (120 mPt) and electricity (127 mPt).

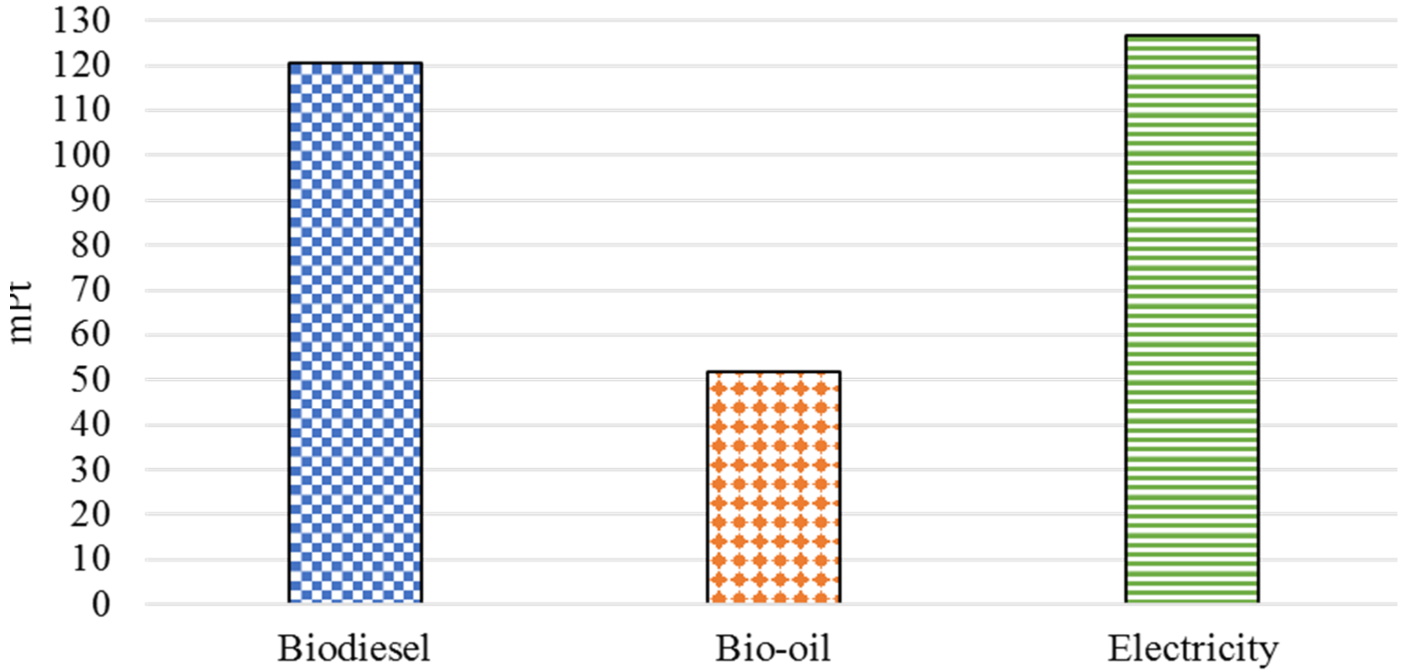


Figure 5. Total environmental impacts of products obtained.

5 Conclusions

4. Conclusions

- The highest electric energy consumption comes from the transesterification stage, which impact represents 23.47 mPt.
- Methanol contributes with 5.26 mPt in the biodiesel production process, where the agricultural stage is the largest contributor of greenhouse gases with 20.39 mPt
- The fast pyrolysis is a good alternative for the treatment of palm oil waste, because does not present major impacts in any of evaluated damage categories.

Acknowledgements

The authors are very grateful to the support provided by the Brazilian National Research and Development Council (CNPq), The Minas Gerais State Research Support Foundation (FAPEMIG) and the Coordinating Body for the Improvement of Postgraduate Studies in Higher Education (CAPES).

Thanks

Any questions?

THANKS A LOT, MUITO OBRIGADO

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