



INTEGRATED EX-ANTE EMERGY EVALUATION OF PRODUCING BIOELECTRICITY FROM ENERGY CANE IN A SMALL ISLAND (GUADELOUPE)

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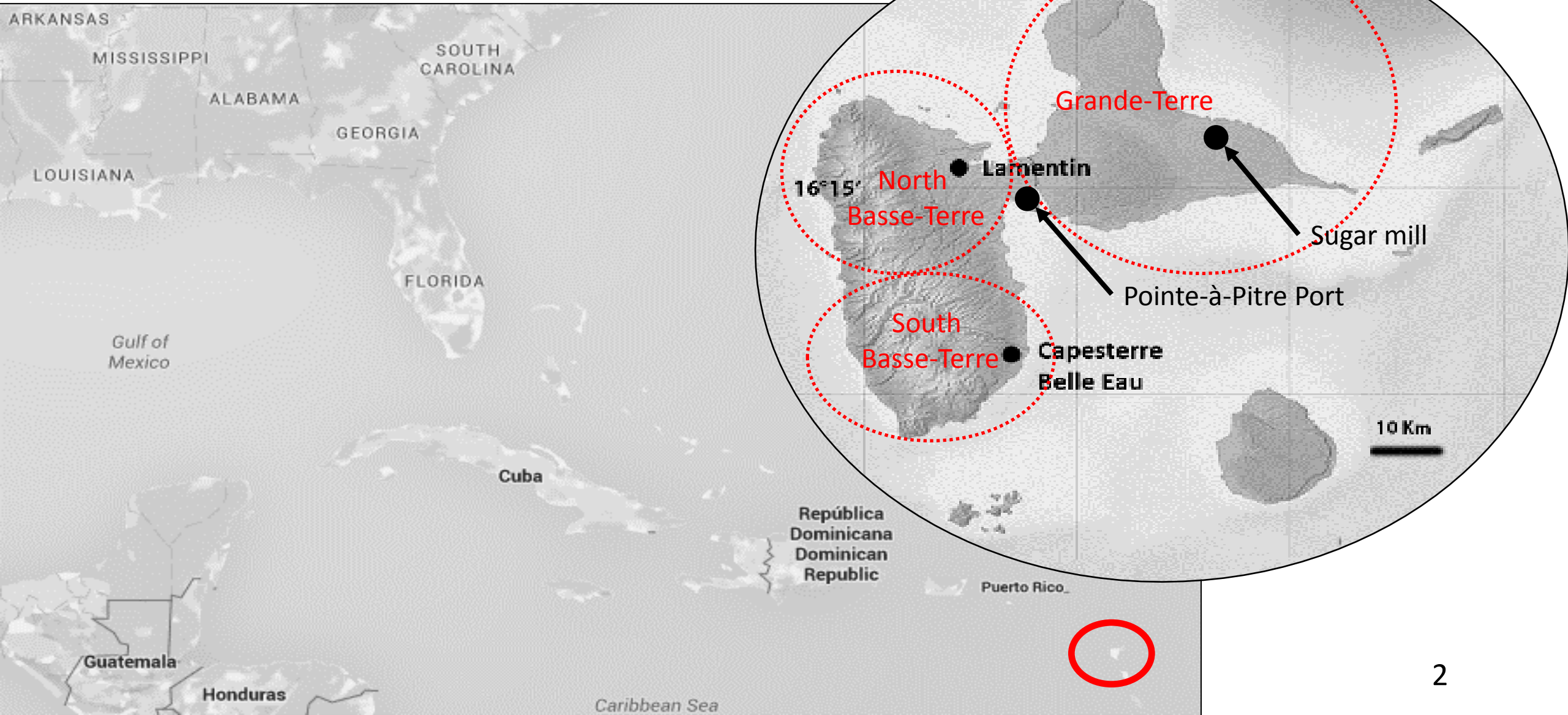
INTEGRATED EX-ANTE EMERGY EVALUATION OF PRODUCING BIOELECTRICITY FROM ENERGY CANE IN A SMALL ISLAND (GUADELOUPE)



STAN SELBONNE, KILLIAN CHARY, AURÉLIE WILFART, LOÏC GINDE,

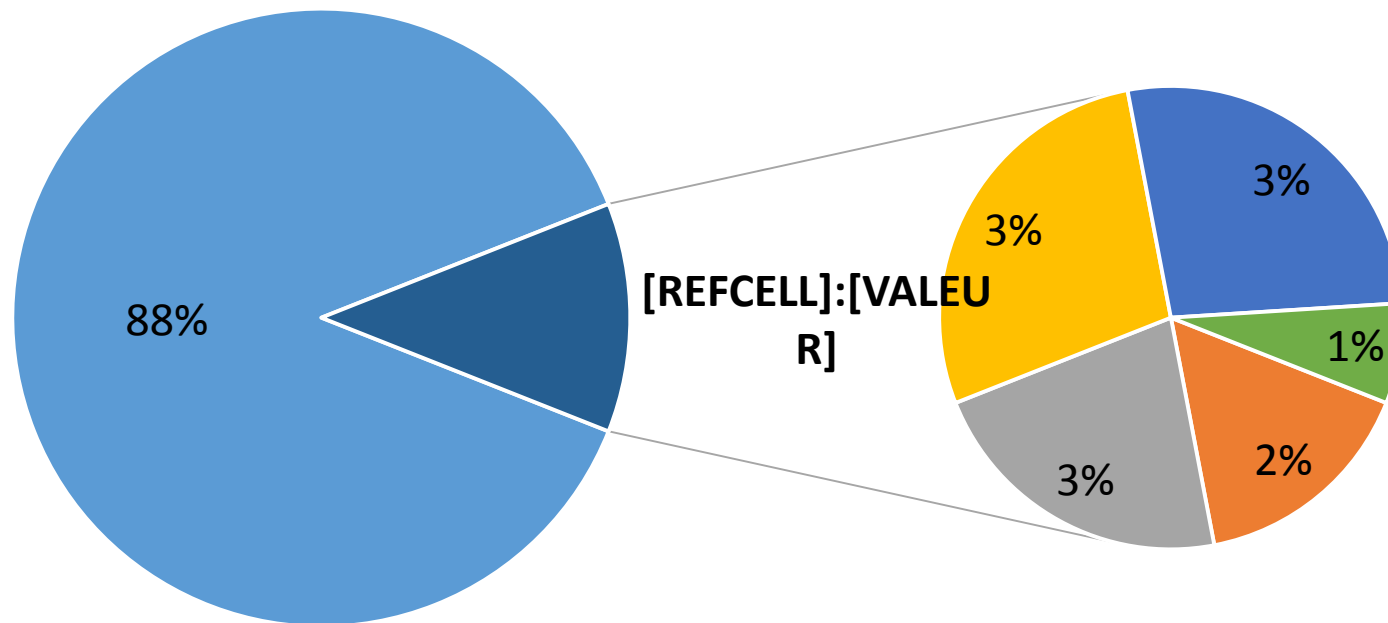
JORGE SIERRA, JEAN-MARC BLAZY

Studied area



Context

Energy mix in Guadeloupe (2014)



■ Fossil fuel

■ Geothermal energy

■ Photovoltaics

■ Bagasse

■ Wind power

■ Hydropower

- 50% of renewable energy over 2020 horizon
- Intermittent energy sources: 30% maximum
- REBECCA project: electricity from energy-cane

☐ Energy-cane

Selection of *Saccharum sp.* for:

- High fiber content
- High yield and growth rate
- Rusticity

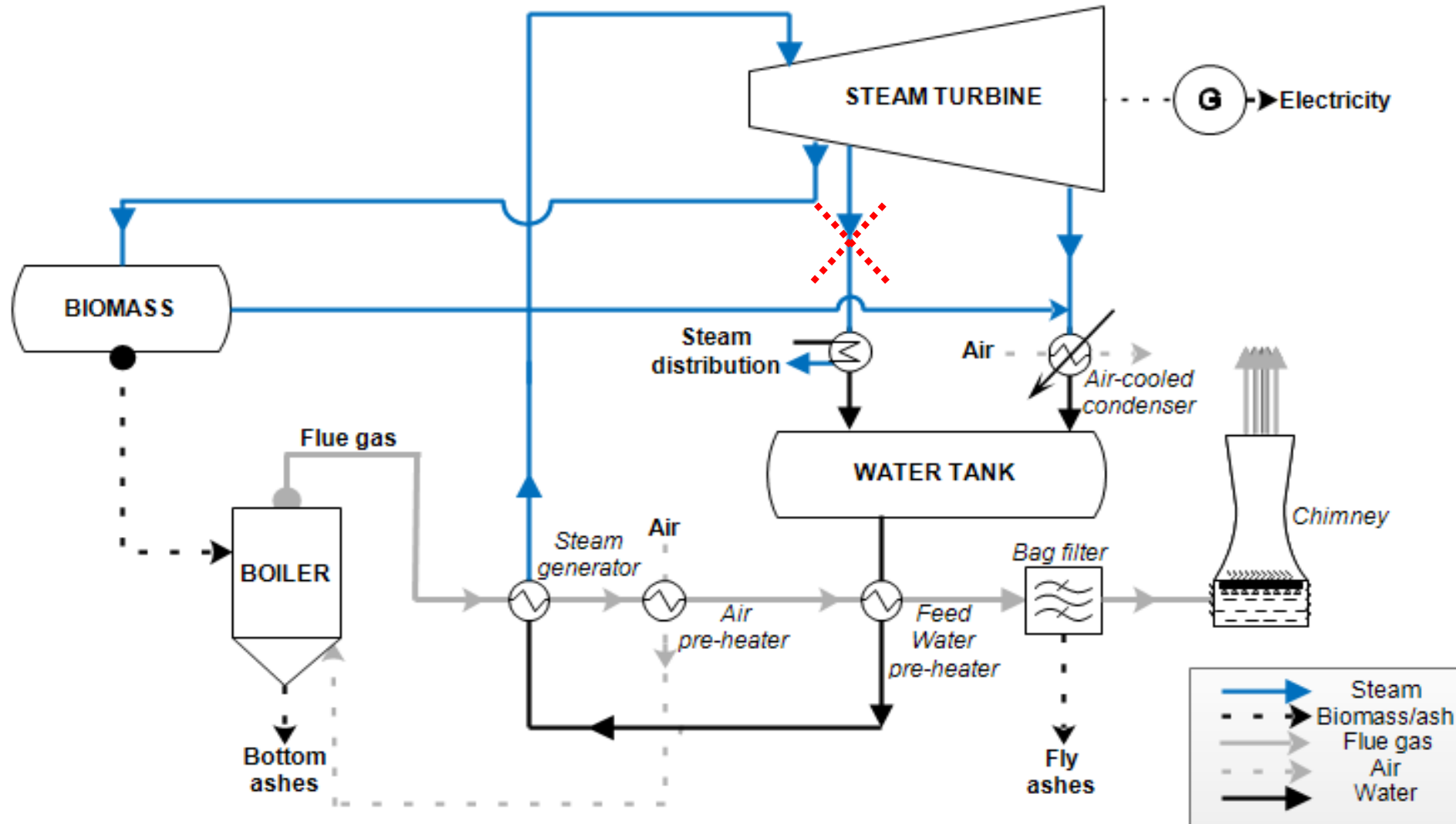


Photo 1: Variety *WI 79 460* at 11.5 months

Table 1: Comparison of energy-cane productivity with four others common biomasses

Original form (% moisture)	LCV (MW.h/t)	Yield (t/ha/y)	Yield (MW.h/ha/y)
Energy cane (65%)	1.20	110	132
Miscanthus (20%)	3.80	17	64.5
Bagasse (50%)	2.08	28	58.2
Switch grass (15%)	3.86	20	77.2
Hardwood (50%)	2.50	10	25.0

❑ The Combined Heat and Power plant (CHP)



- **Electrical yield: 27%**
- **No steam outlet**
- **Air-cooled condenser**

□ The biomass production



Conventional energy-cane

- 6 years cycles
- No irrigation
- Herbicides
- Mineral fertilizers
- Mechanical harvesting
- Subsidies



Imported pellet

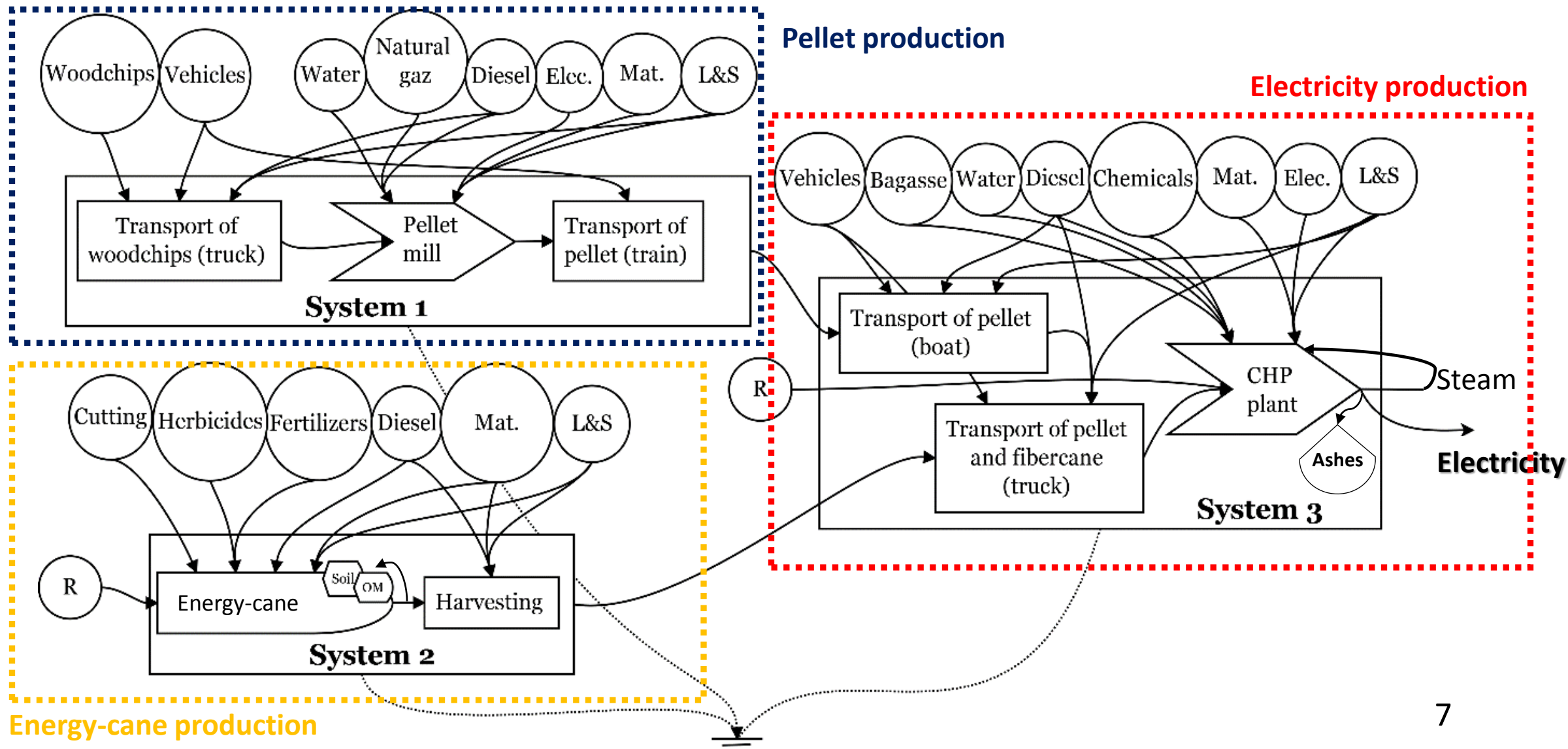
- Data from literature
- Plant located in Georgia (US)
- Woodchips from natural forest logging
- 9000 t/yr pellet plant



SMART energy-cane

- 6 years cycles
- No irrigation
- Mineral fertilizers
- Mechanical harvesting
- Mechanical weed management
- All the biomass harvested
- Compost amendment
- Additional subsidies

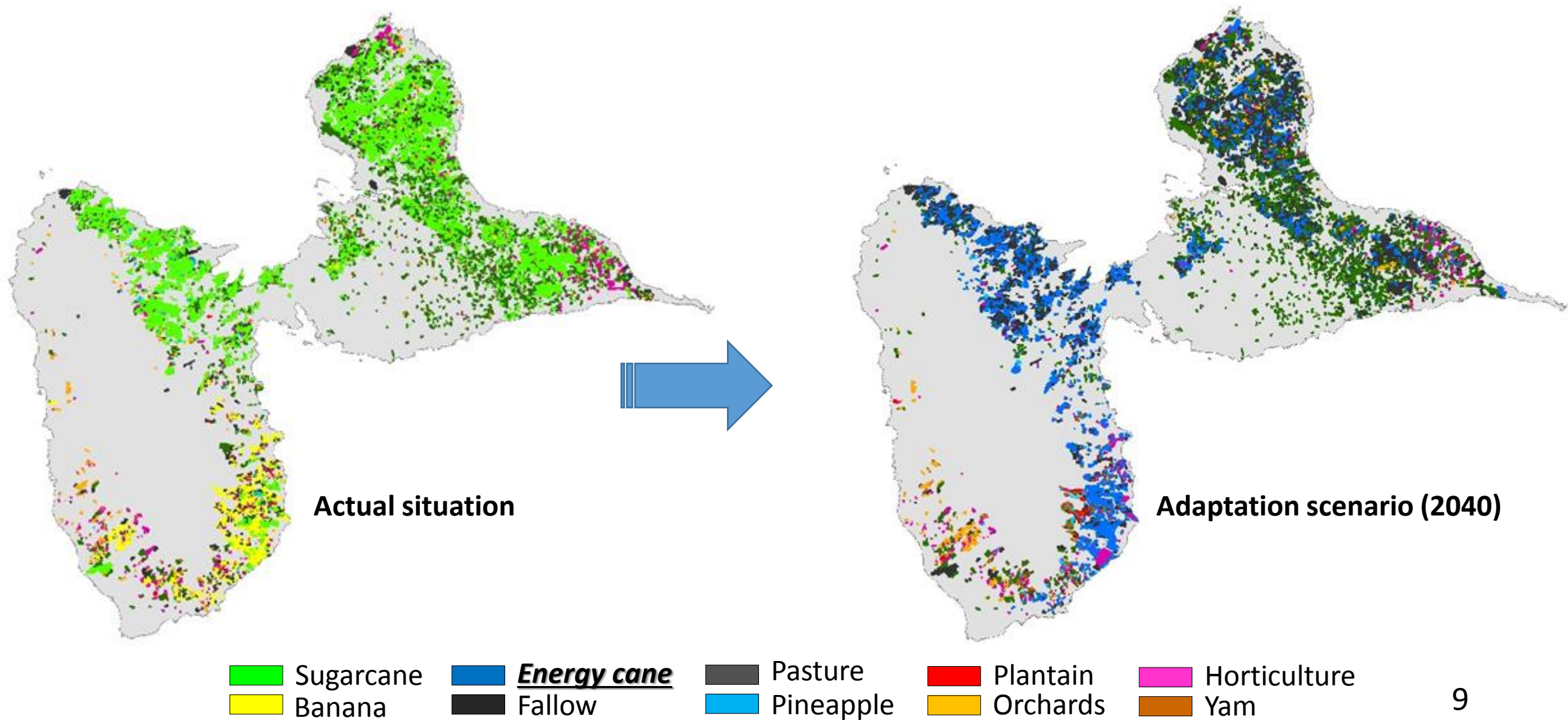
□ The agro-industrial sector



❑ The four scenarios

SENARIOS	S0 Baseline	S1 ("SMART")	S2 (Pellet)	S3 (Micro-"SMART")
Plant’s capacity (MWth)	40	40	40	4
Energy-cane in energy mix	70%	70%	25%	100%
Pellet in energy mix	25%	25%	70%	0%
Bagasse in energy mix	5%	5%	5%	0%
Plant localisation	Lamentin	Lamentin	Capesterre	Capesterre
Crop management system	Conventional	SMART	Conventional	SMART

□ Energy cane crop adoption by farmers (MOSAICA, *Chopin et al., 2015*)



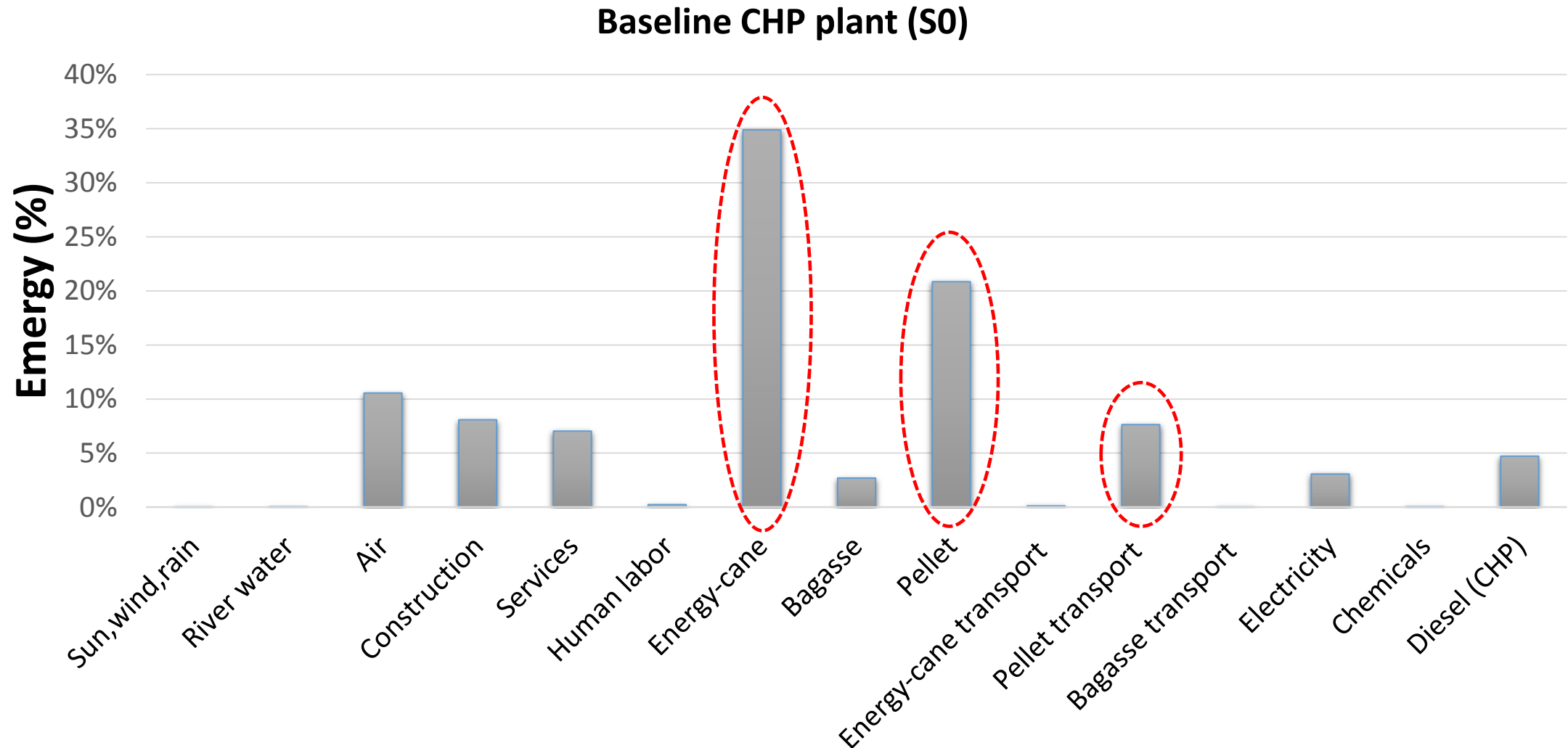
□ Emergy indicators

Indicators	Expression	Meaning
Unit emergy value (UEV)	Y / E	▪ The ratio of the emergy of the output (Y) to the energy of the products (E)
Renewability (%R)	$100 * (R + M_R + S_R) / Y$	▪ The ratio of local renewable emergy (R) plus purchase renewable materials (RM) and services (RM) input, to the total emergy output (Y)
Renewable efficiency indicator (REI)	$UEV / (\%R)$	▪ The ratio of efficiency to the percentage of renewability
Environmental loading ratio (ELR)	$(N + M_N + S_N) / (R + M_R + S_R)$	▪ The ratio of non-renewable emergy to renewable inputs
Emergy yield ratio (EYR)	$Y / (M_N + S_N)$	▪ The ratio of total emergy used to the emergy of non-renewable inputs from the economy
Emergy sustainability index (ESI)	EYR / ELR	▪ Indicates the relative sustainability of the system

□ Indicators obtained for the four scenarios

Indicators	S0 (Baseline)	S1 ("SMART ")	(Δ)	S2 (Pellet)	(Δ)	S3 (Micro-"SMART")	(Δ)
UEV (seJ/J)	3.11E+05	3.05E+05	-2%	3.88E+05	+25%	2.94E+05	-5%
%R	30.21	38.07	+26%	30.94	+2%	36.91	+22%
ELR	2.31	1.63	-29%	2.23	-3%	1.45	-37%
EYR	1.12	1.12	0%	1.09	-3%	1.13	+1%
ESI	0.48	0.69	+44%	0.49	+2%	0.78	+63%
REI (seJ/J)	1.03E+04	8.01E+03	-22%	1.25E+04	+22%	7.97E+03	-23%

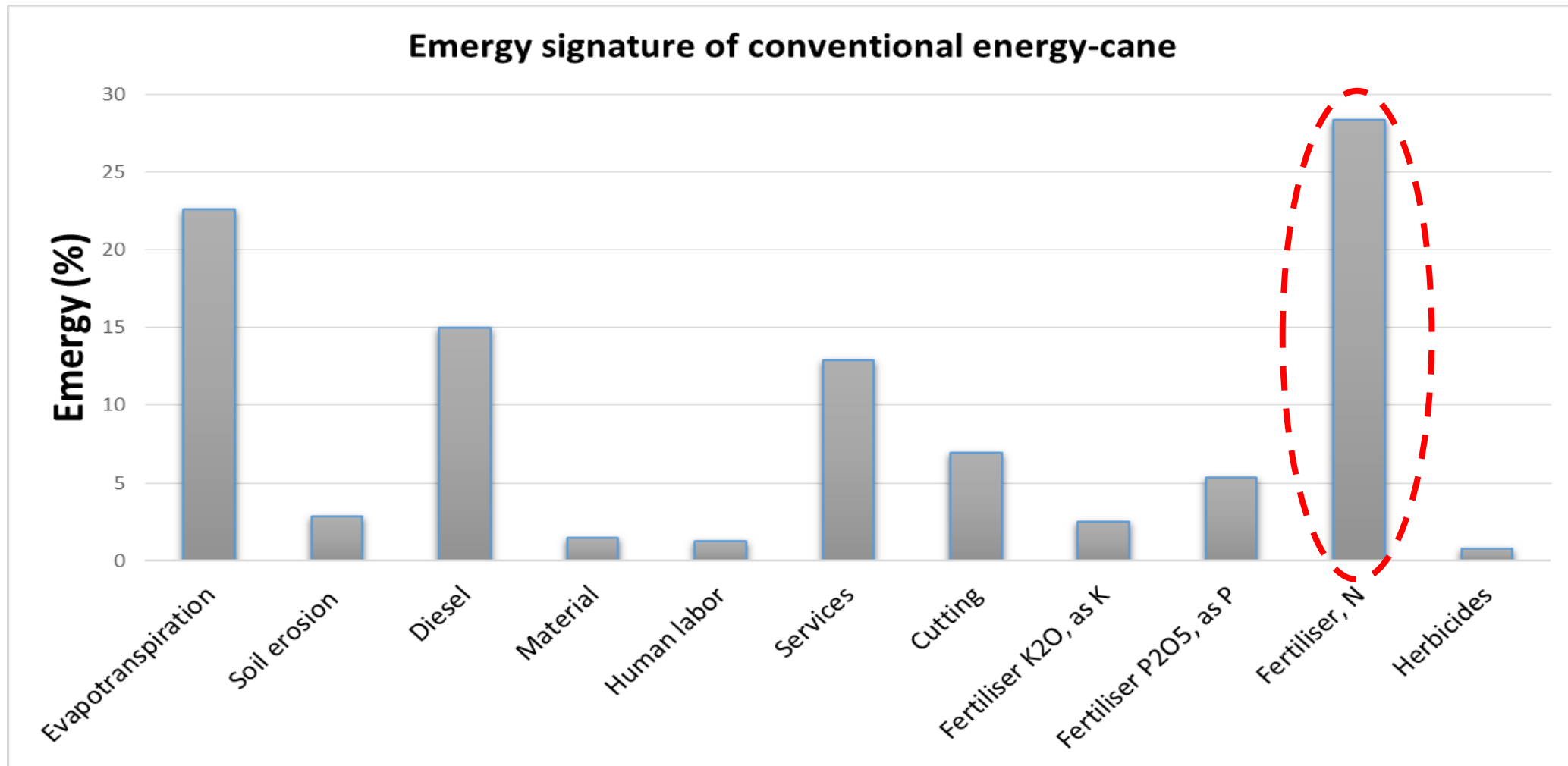
□ Energy signature of electricity production (baseline scenario S0)



□ UEVs and renewable fractions calculated for the different biomasses

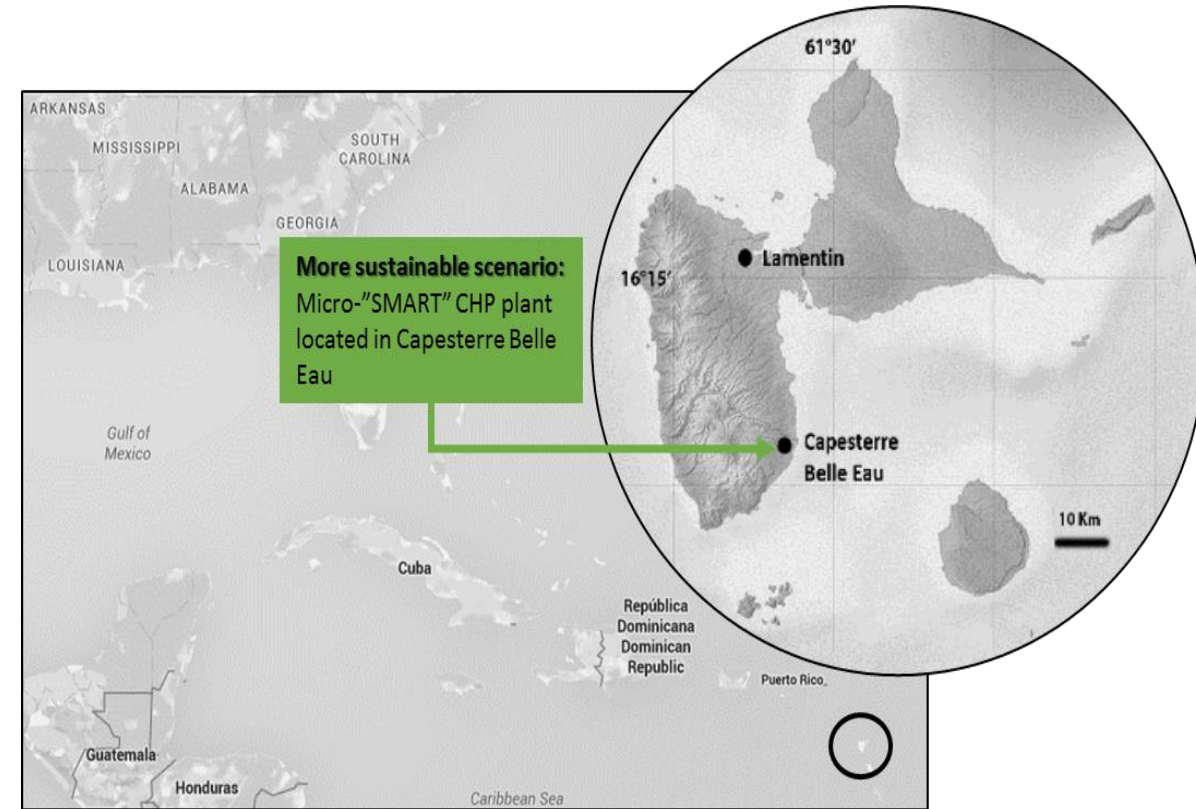
Biomass	UEV (seJ/J)	%R (%)	REI (seJ/J)
Conventional Energy-cane	4.14E+04	26	1.59E+03
Conventional Energy-cane (<i>with transport for S0</i>)	5.95E+04	18	3.31E+03
Pellet	6.63E+04	47	1.41E+03
Pellet (<i>with transport for S0</i>)	1.65E+05	15	1.10E+04
“SMART” energy-cane	3.98E+04	54	7.37E+02
“SMART” energy-cane (<i>with transport for S1</i>)	4.53E+04	48	9.44E+02

□ Emergy signature of conventional energy-cane (without transport)



❑ Conclusion

- ❑ Overall, even without steam market the baseline scenario presented energy indicators in range of values found in similar studies.
- ❑ Pellets presented better indicators than local energy-cane, but the weight of the transport reversed the results.
- ❑ REI should be used for the comparison of UEV and renewability between different products
- ❑ Through the three other scenarios analysed, we showed that the indicators of electricity produced was very sensible to the biomass used, except for EYR indicator.
- ❑ The use of “SMART” crop management system allowed to produce a biomass more sustainable with an UEV (with transport) of $4.53E+04$ seJ/J and a high renewability of 48%.
- ❑ The implantation of the smaller CHP plant which operated with 100% “SMART” energy-cane was more sustainable than baseline scenario, surpassing the scale economy issue.
- ❑ Nitrogen fertilizers was the most impacting input in energy-cane crops.



Thank you for your attention!

