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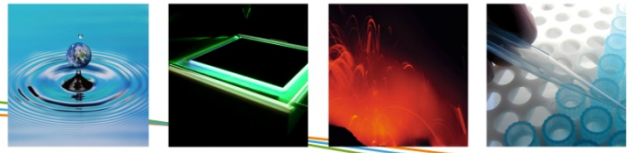

Energy valorization and human health: Biomass-to-energy potential in Cuba

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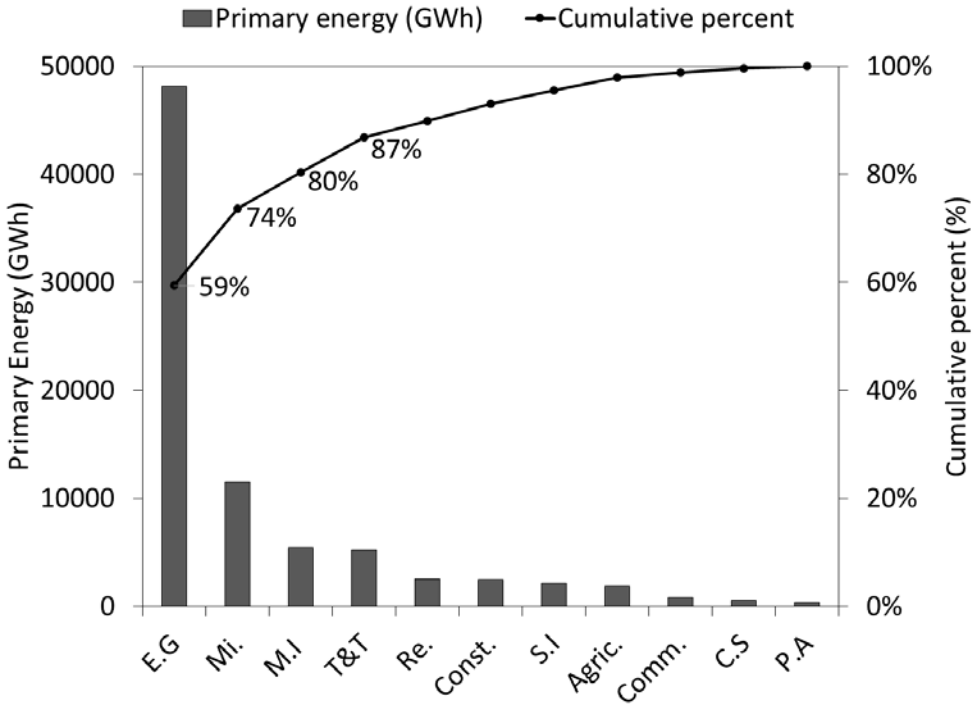
Introduction

- Low carbon society
- Carbon neutral buildings, sectors,cities
- Carbon neutral countries?
- Worldwide electricity generation causes 25% of the GHG-emissions (IPCC)
- Opportunities in countries with a low electricity consumption and favorable conditions

Electricity in Cuba: Primary energy consumption



Source: Oficina Nacional de Estadística (http://www.one.cu)

Legend

E.G	Electricity generation
Mi.	Mining
M.I	Manufacturing industry
T&T	Transport and telecommunication
Re.	Residential
Const.	Construction
SI.	Sugar industry
Agric.	Agriculture
Comm.	Commerce
C.S	Company services
P.A	Public administration

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Electricity in Cuba

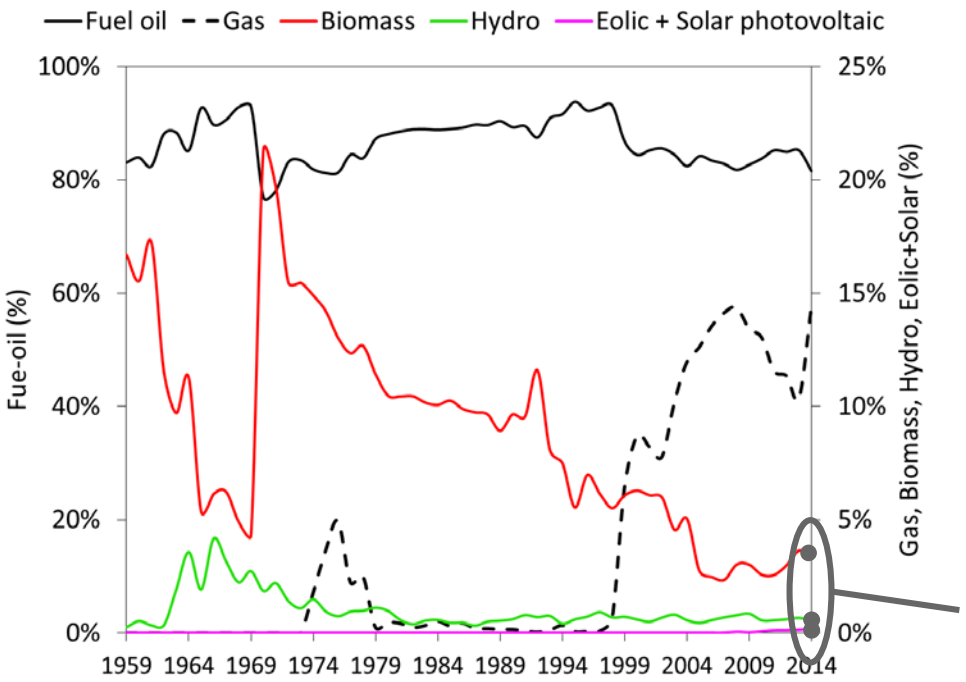
- Cuban electricity almost only imported fossil fuel based
- Government plans increasing the electricity generation from biomass from the current 3% to 24% by 2030
- Will reduce the carbon footprint; will make Cuba more self-supporting

Energy source	Electricity generation (GWh)	Share in energy mix (%)
Fuel oil	15,652	84.92
Gas	2,092	11.35
Biomass	555	3.01
Hydro	111	0.60
Wind	17	0.09
Solar photovoltaic	5	0.03

Fossil fuels: 96.27 %

http://www.iea.org/statistics/statisticssearch/report/?year=2012&country=Cuba&product=ElectricityandHeat

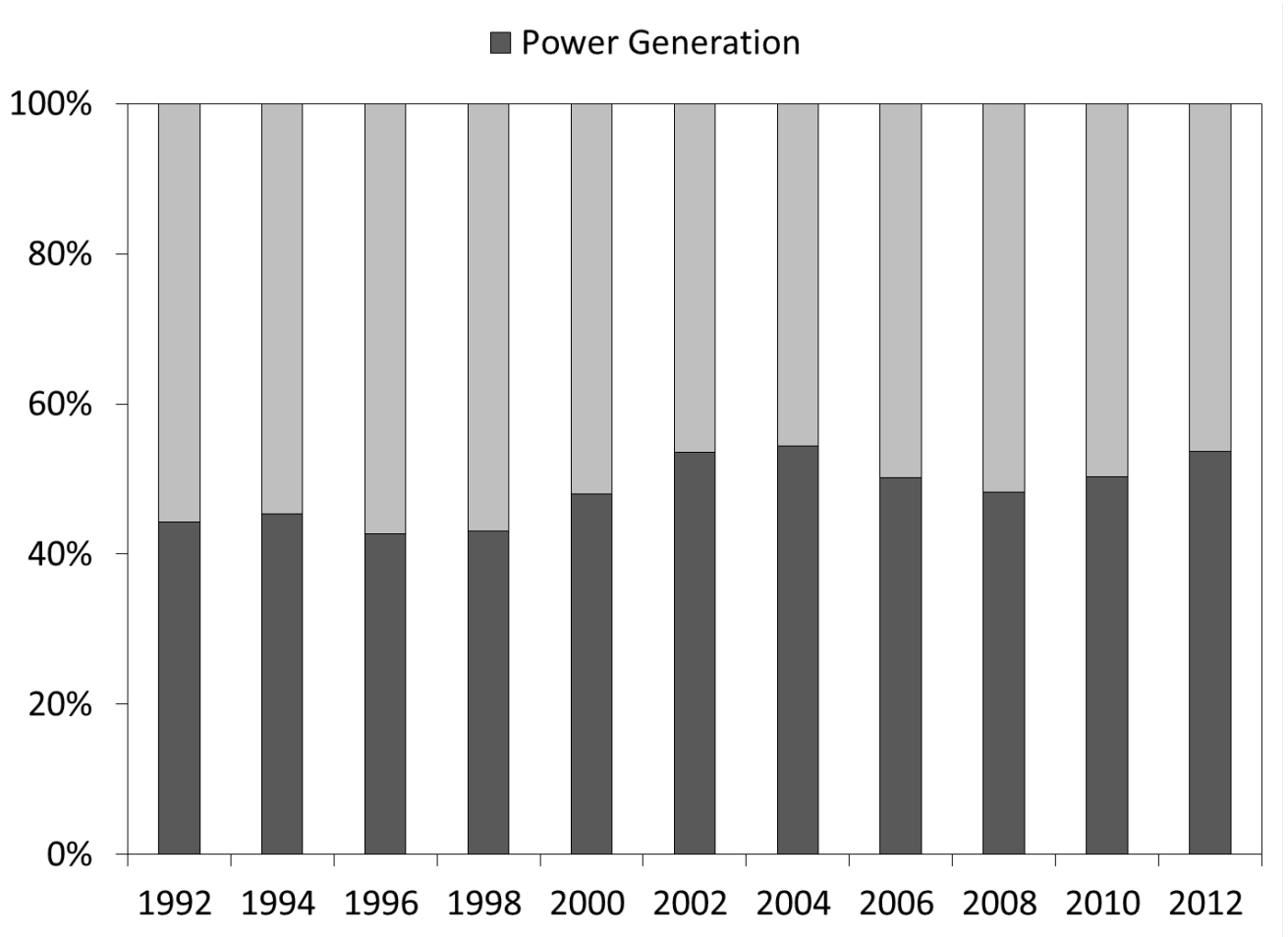
Electricity mix evolution (1959-2014)



Renewable based electricity: < 5%

Source: Oficina Nacional de Estadística (http://www.one.cu)

Relative GHG emissions in Cuba



Biomass sources in Cuba

	Biomass source	Quantity (kt/y)
Agriculture	Rice husk	1
Agriculture	Sugarcane straw	57
Sugar industry	Bagasse	459
Sugar industry	Filter cake	63
	Dichrostachys cinerea (Marabu)*	2,553
	Pig manure	166
	Municipal solid waste (MSW)**	113

Sugar cane - bagasse

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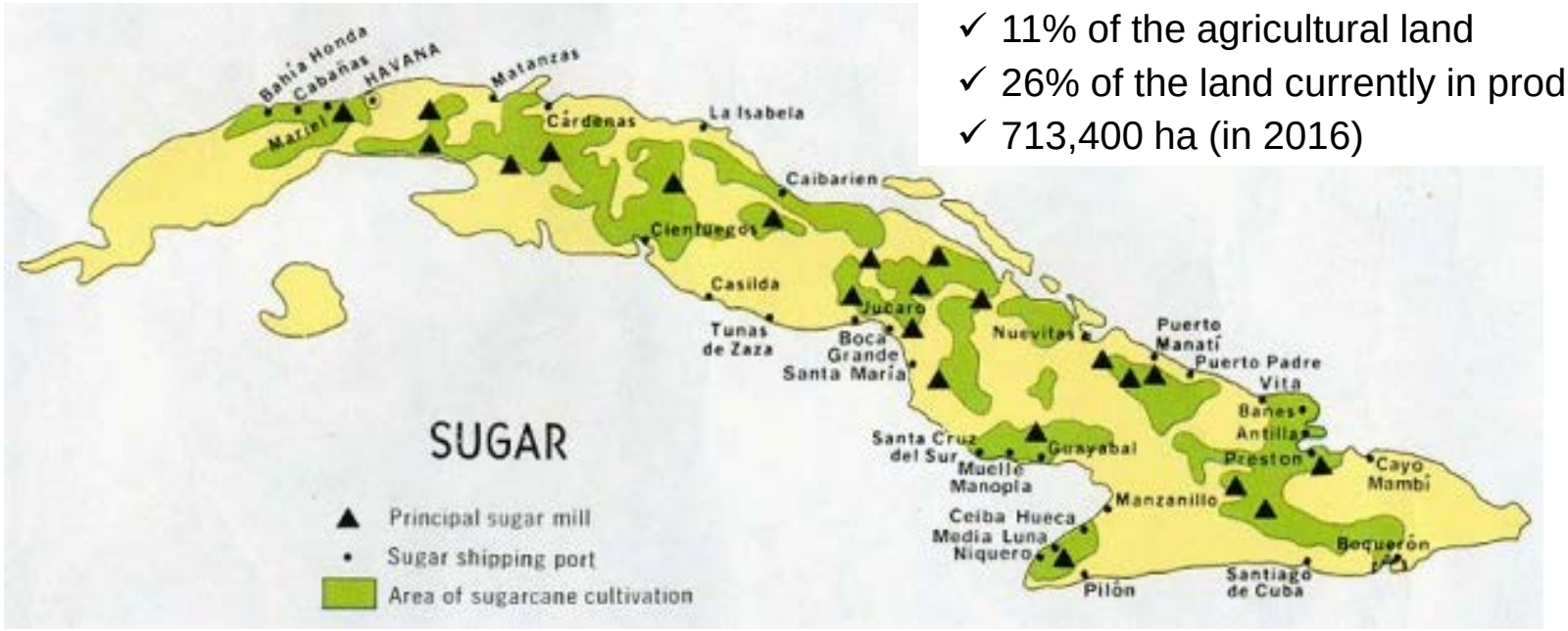
Sugarcane fields in Cuba

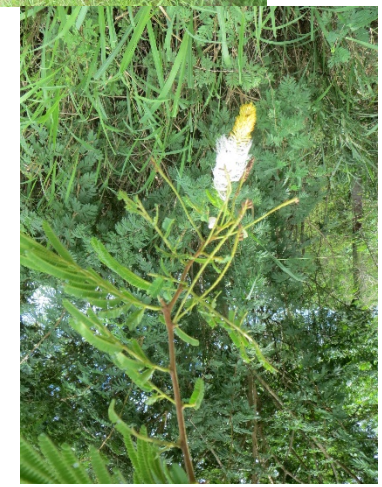
Sugarcane fields (http:// www.one.cu):

- ✓ 6.5% of the national territory
- ✓ 11% of the agricultural land
- ✓ 26% of the land currently in production
- ✓ 713,400 ha (in 2016)



Source: http://mapas.owje.com/tematico/19/mapa-tematico-cuba.php

Marabu (Dichrostachis cinerea)



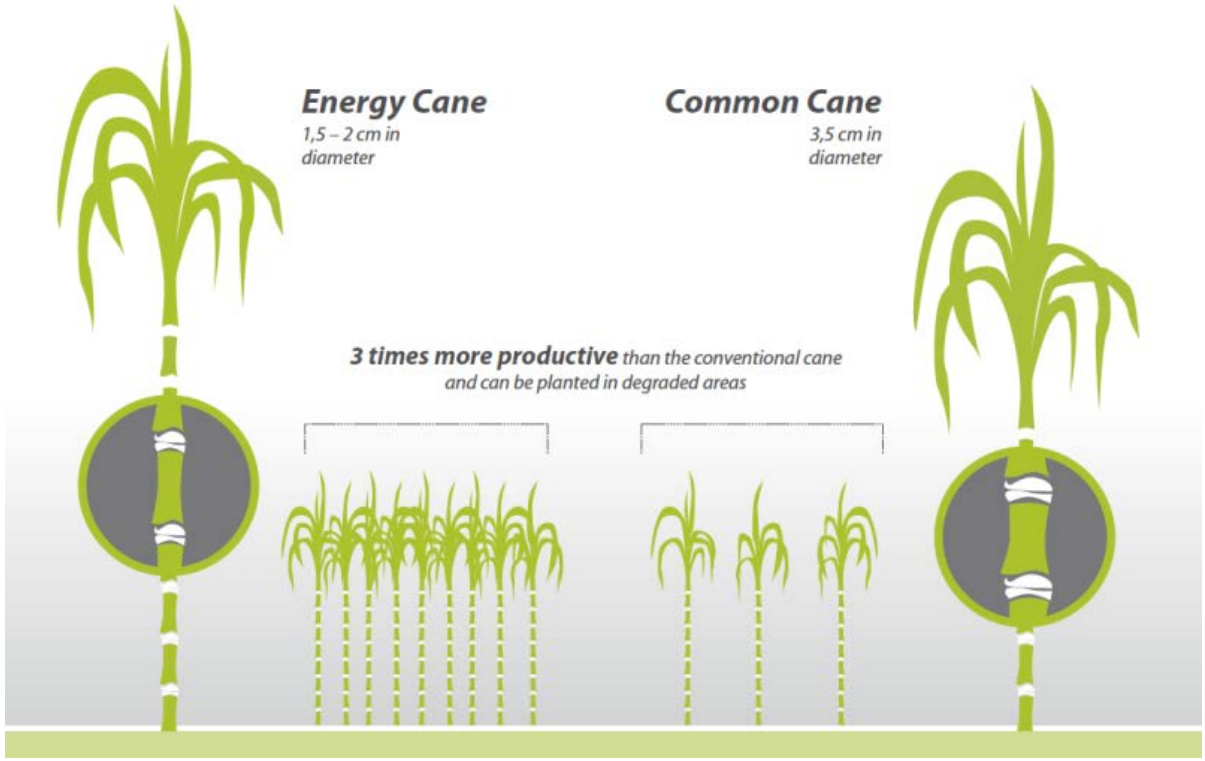
Marabu (Dichrostachys cinera)

1. Non-indigenous bush plant
2. Can be incinerated after the milling season
3. Biomass 37 t/ha regrown in 3 years
4. Generates

    1.268 kWh/t marabu

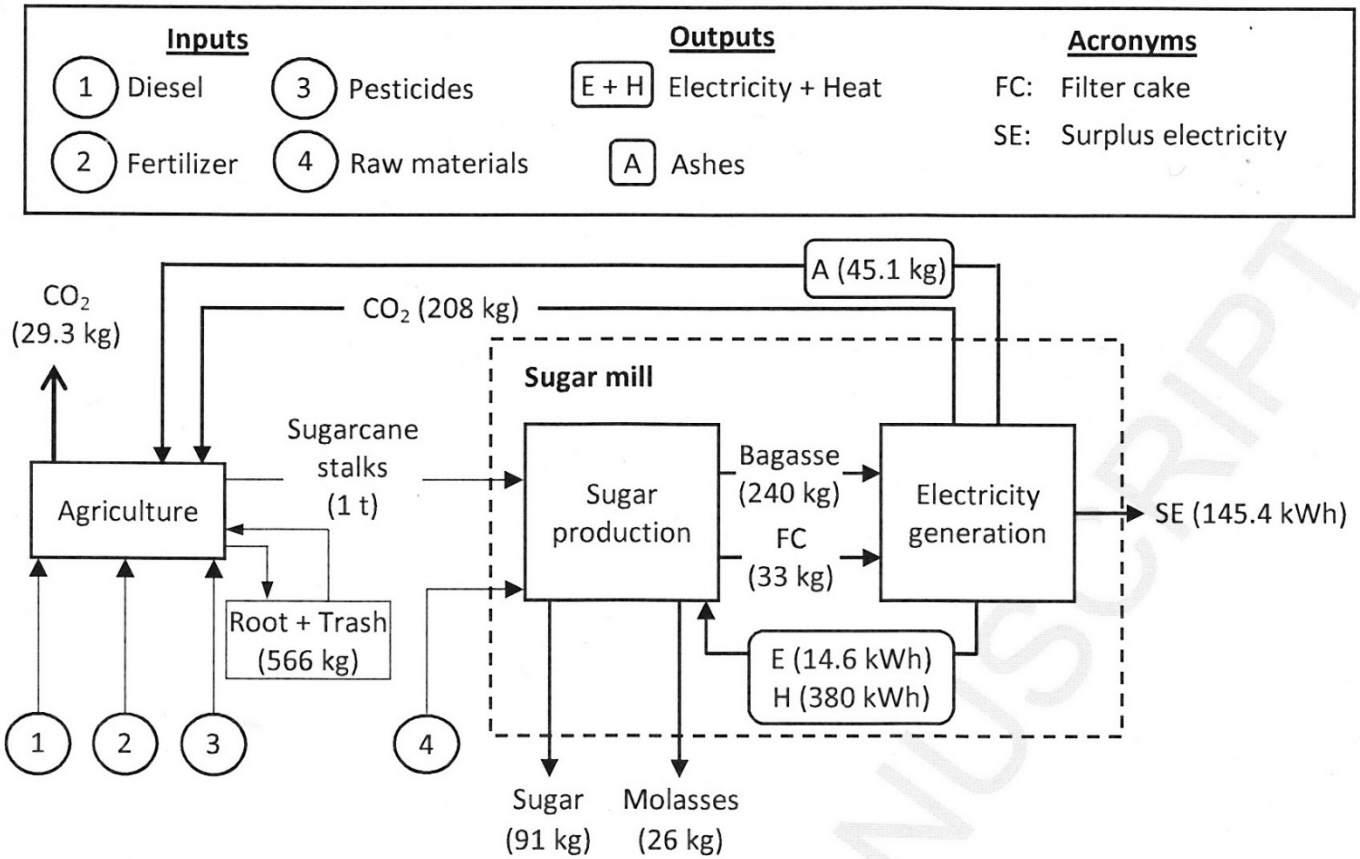
    15.9 kg CO_2eq/t marabu

Energy cane



http://www.granbio.com.br/en/conteudos/energy-cane/

LCA approach to GHG emissions from sugar cane (90 t/ha)



Scenario 1

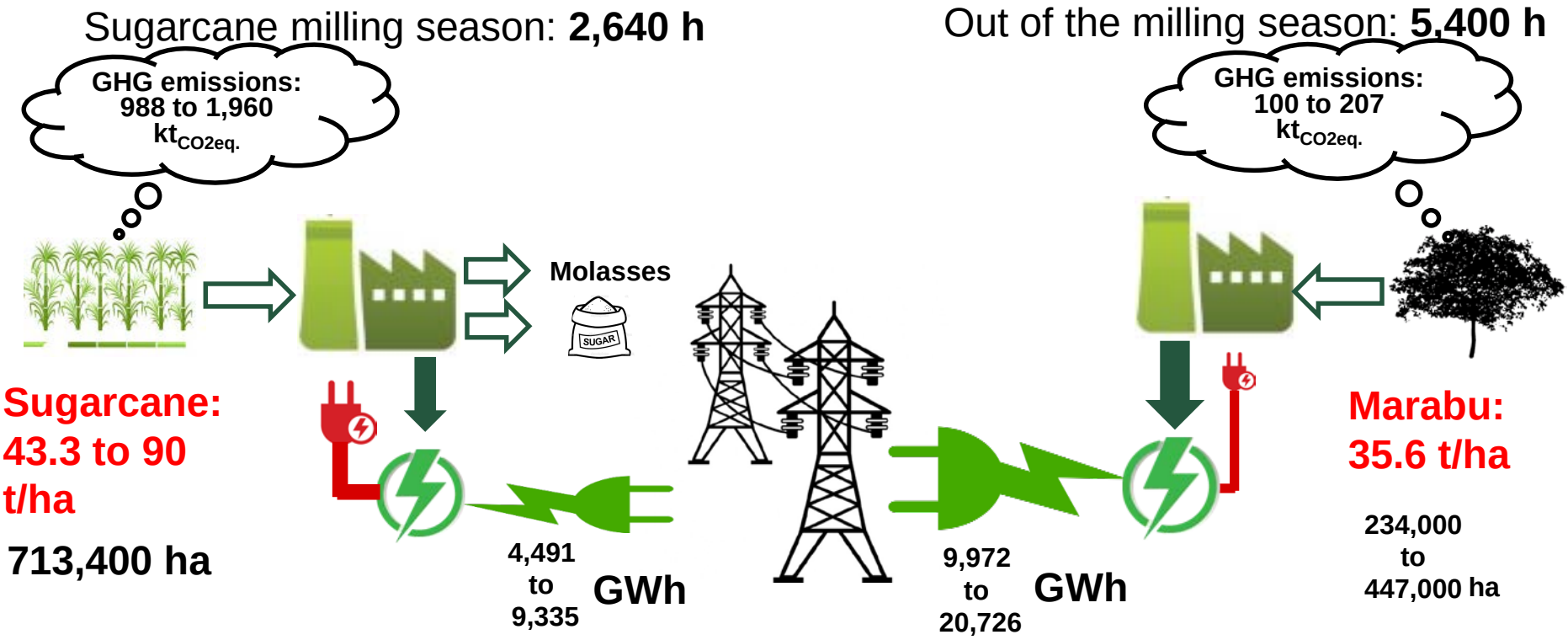
- Variety of renewable energy sources
- Biomass: In 19 sugar plants (15-60 MW each)
- Wind: 13 fields (36-51 MW each)
- Hydro: 74 power plants (0.5-10.9 MW each)
- Solar: Not specified (1000 GWh/y)
- Total: 7.319 GWh/y
- GHG emissions: Net reduction 6200 $ktCO_2eq$
- Investment: 255 million $US/year until 2030

Scenario 1

Renewable source	Power (MW)	Electricity (GWh/year)	Share (%)	Power plants	Investment (million USD)	Cost (USD/kW)	Saved emissions ($kt_{CO2}eq.$)
Biomass	755	4,357	14	19	1,290	1709	3,700
Eolic	633	1,636	5	13*	1,120	1769	1,400
Solar	700	1,088	4	-	1,050	1500	900
Hydraulic	56	238	1	74	110	1964	200
Total	**2144**	**7,319**	**24**	**-**	**3,570**	**-**	**6,200**

*Eolic fields

Scenario 2: Sugarcane + Marabu



Scenario 2

- Bagasse and dewatered filter cake during the milling season and marabu during the remaining part of the year
- 44.3 t/ha sugar cane allows producing 1854 MW
- 267000 ha/y marabu (50% of the current Marabu area)
- Current figures can be optimized
- 31000 $ktCO_2eq$ emission reduction of GHG
- Investment: 3 million $US/y until 2030

Scenario 3

- Bagasse and filter cake (milling season) and energy cane (outside milling season)
- 212000 ha/y of energy cane
- Allows producing 12750 GWh which is 48% of the electricity planned for 2030
- Current figures can be optimized
- 37 % reduction of 2012 GHG emissions
- Investment: 13 million $US/year until 2030

Scenarios 2 and 3

Scenario	Biomass	Yield (t/ha)	Mass (kt)	Power capacity (MW)	Surplus electricity (GWh)	Saved emissions ($ktCO_{2eq}$)	Power generation period (h)
2 and 3	Bagasse	44.3*	7,585	1,897	3,970	2,648	2,640
	Filter cake		1,043		625	548	
2 and 3	Bagasse	90*	15,409	3,853	8,066	5,323	
	Filter cake		2,119		1,269	1,113	
2	Marabu	35.6	8,078	1,897	10,243	8,875	5,400
			16,411	3,853	20,809	18,030	
3	Energy cane	141	29,822	1,897	9,944	8,112	
	Energy cane		60,586	3,853	20,203	16,480	

*Sugarcane yield

Optimization

- Agriculture
- More combustion sources
- Technology
- Low carbon/renewable electricity generation

Biomass strengths

- Biomass can be incinerated 24/7, stored, continuously provided
- Contribute to a reduction of GHG emissions

Biomass weaknesses

- Incinerator emissions: Particulates, NOx, PAH, reactive sulfur and chlorine emissions, …; secondary aerosols
- Biomass incineration is worldwide the single largest source of CH_3Cl
- Local/global effects on air quality; varies with geography, latitude, season, day of the week, operation of the plant, etc.
- Through bottom and fly ash effects on soil and water (PAH, heavy metals)
- Professional exposure: health risks in pre-combustion,

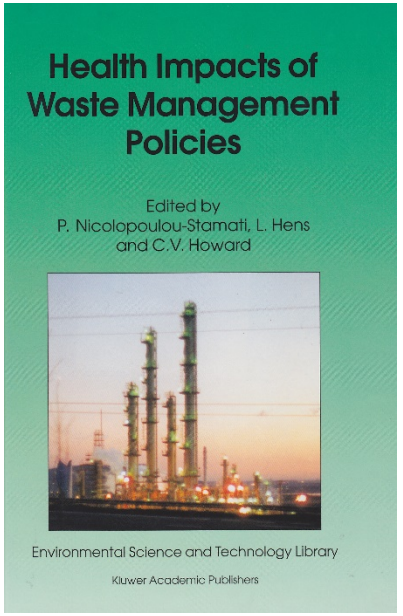
  combustion, post-combustion mainly trough exposure trough particulates, NOx, reactive chlorines
- Airways (upper, lower), irritation of the mucous membranes e.g. of eyes

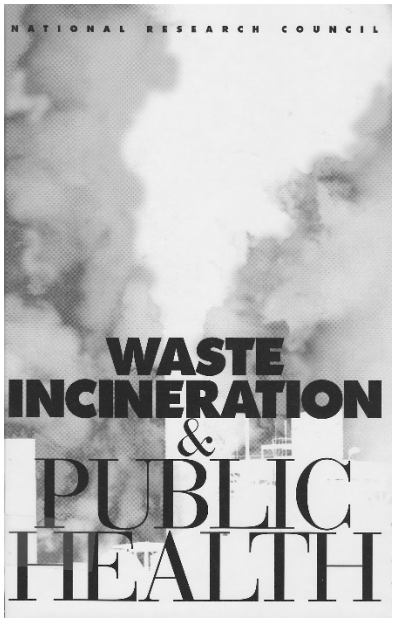
Health effects in professionals exposed to biomass incineration

SSH Class	SSH	Source	Refs	Health Effects Associated with Exposure Route		Refs
				Inhalation	Dermal/Eye	
Inorganic Gases	Carbon monoxide	Combustion	[45]	CNS; Miscarriage; Carboxylhemoglobinemia		[45,46]
	Nitrogen oxides	Combustion	[45]	URT and LRT	Irritation (Skin and Eye)	[45,48]
	Sulfur oxides	Combustion	[46]	Pulmonary function; LRT		[45,49]
	Acid aerosols (e.g., H_2SO_4)	Combustion	[47]	Pulmonary function	Irritation (Skin and Eye)	[45,49]
Hydrocarbons	1,3-Butadiene	Combustion	[45]	CNS; Stomach, Respiratory and Hematolymphopoietic Cancers		[45,50]
	n-Hexane	Combustion	[45]	CNS; Peripheral Neuropathy	Irritation (Eye)	[45]
	PAHs [a]	Combustion, Ash	[45,48,49]	Lung Cancer	Skin Cancer *	[51]
	Benzene	Combustion	[45]	Leukemia; Anemia; CNS		[45,52]
	Styrene	Combustion	[45]	CNS		[45]
Oxygenated organics	Acrolein	Combustion	[45]	URT; Pulmonary edema; Pulmonary emphysema	Irritation (Skin and Eye)	[45]
	Formaldehyde	Combustion	[45]	URT; Nose Cancer *	Irritation (Skin and Eye)	[45,53]
	Methanol	Combustion	[45]	CNS; URT	Eye Damage	[45,54]
	Acetic acid	Combustion	[45]	URT; Pulmonary function	Irritation (Eye)	[45]
	Catechol	Combustion	[45]	URT	Dermatitis; Irritation (Eye)	[45]
	Cresol (methylphenols)	Combustion	[45]	URT; Kidney; Liver	Skin Damage	[45,55]
	Hydroquinone	Combustion	[45]	CNS	Irritation (Eye)	[45,56]
	Fluorenone	Combustion	[45]	URT	Irritation (Eye)	[57]
	Anthraquinone	Combustion	[45]	Respiratory	Irritation (Skin and Eye)	[58]
Chlorinated organics [b]	Methylene chloride	Combustion	[45]	CNS; Peripheral Neuropathy; Liver and Lung Cancer *	Irritation (Skin and Eye)	[59,60]
	Methyl chloride	Combustion	[45]	CNS; Liver; Kidney; CNS *; Testicular *; Teratogenic *		[45,61]
	Dioxins/furans	Combustion	[45,48]	URT; Chloracne; Liver; Glucose metabolism	Chloracne	[62,63]
Particulate matter (PM)	PM_{10}	Combustion/ Condensation	[45]	Pulmonary function; URT	Irritation (Eye)	[64]
	$PM_{2.5}$	Combustion/ Condensation	[45]	Pulmonary function; URT	Irritation (Eye)	[22]
Inorganics	Aluminum (Al) [c]	Combustion	[45]	Pneumoconiosis; LRT		[45,66]
	Arsenic (As) [e]	Ash	[48,49]	URT and LRT; Lung Cancer		[45,67]
	Beryllium (Be) [d]	Ash	[48]	Beryllium disease;	Irritation (Skin)	[45,68, 69]
	Cobalt (Co) [d,e]	Ash	[48]	Pulmonary function; Myocardial effects		[45,70]

Direct health effects public health

- Particulates (in particular <2.5 mm and <1 mm)
- * Initiate and worsen asthma
- * Increase hospital admissions (bronchitis, asthma)
  * Increase emergency visits (respiratory diseases)
- * Reduction of lung function
- * Increased upper respiratory system symptoms
- * Increase heart disease incidence
- Vulnerable groups: Babies, children, elderly





Conclusions

- It s feasible realizing the government targets in Cuba: 24% of the electricity demand by a mixture of renewable energies.
- It is equally feasible covering over 96% of the electricity demand by biomass.
- Both options require supporting initiatives on reserve electricity generating capacity, upgrading the existing incineration technology, and research e.g. on other applications of renewable energy.
- Both options allow reducing the 2012 GHG emissions by respectively 20% (government option) and 81% (scenarios 2 and 3).
- It is indicated coupling a biomass scenario with an environmental health program.

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Thank you
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Kiitos
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Hvala
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Obrigado
Merci
Danke
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Gracias
Grazie
Thank you
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