Sustainability of ethanol production in Mexico

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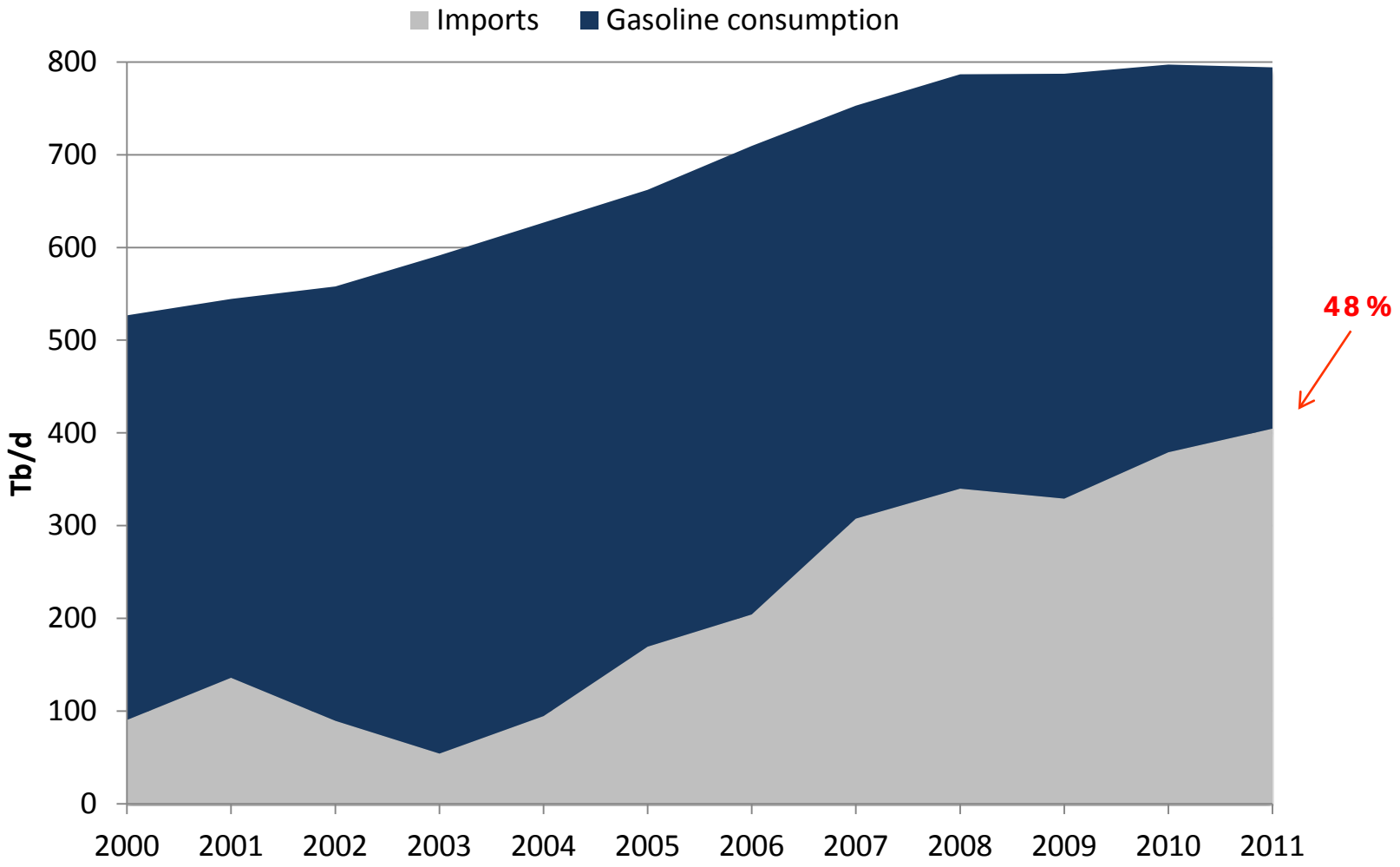
Gasoline and diesel imports in Mexico



Source: Energy Information System. SENER.

Gasoline and diesel imports in Mexico

Potential for first-generation ethanol production in Mexico.

Energy crops	Mha	Yield t/ha	Production ML	Production PJ	% Gasoline consumption (2011)
Molasses (C molasses)	1.664 **[a]		391[a]	8	0.6%
Sugarcane	2.9*	40-120*	14449*	338*	22.5%
Corn	4.5*	0.8-2.5*	2028*	44*	2.9%
Sorghum	2.6*	2.2-4.2*	3900*	84*	5.6%
Total			14523	460	31.6%

Source: García et al. 2014

Ethanol Modalities

Crop	*Ethanol source /Technology*	*Water source*	*Fertilization kg/(ha*Y)*	*Yield (t/ha)*	*Energy source for etOH*	*Products / co-products*
SUGARCANE	**C Molasses**	**Rainwater**	**126:41:150**	**70**	**Bagasse**	**Sugar/Anhydrous Ethanol**
SUGARCANE	**Juice**	**Rainwater**	**126:41:150**	**70**	**Bagasse**	**Anhydrous Ethanol/Electricity**
SORGHUM MEDIUM	**Dry mill**	**Rainwater**	**0**	**2.5**	**Natural Gas**	**Anhydrous Ethanol/DDGS**
SORGHUM HIGH	**Dry mill**	**Irrigation**	**189:70:00**	**5.4**	**Natural Gas**	**Anhydrous Ethanol/DDGS**
CORN LOW	**Dry mill**	**Rainwater**	**0**	**1**	**Natural Gas**	**Anhydrous Ethanol/DDGS**
CORN MEDIUM	**Dry mill**	**Irrigation**	**210:00:00**	**5**	**Natural Gas**	**Anhydrous Ethanol/DDGS**
CORN HIGH	**Dry mill**	**Irrigation**	**263:161:00**	**9**	**Natural Gas**	**Anhydrous Ethanol/DDGS**

Indicators

Energy Indicator (Ie)

(EROEI) Ethanol E/ Fossil E (GJ)

Environmental Indicator (Ia)

kg CO_2e/GJ

Water use Indicator (Iua)

m_3/GJ

Economic Indicator (Iec)

Production cost USD/L

Social Indicator (Is)

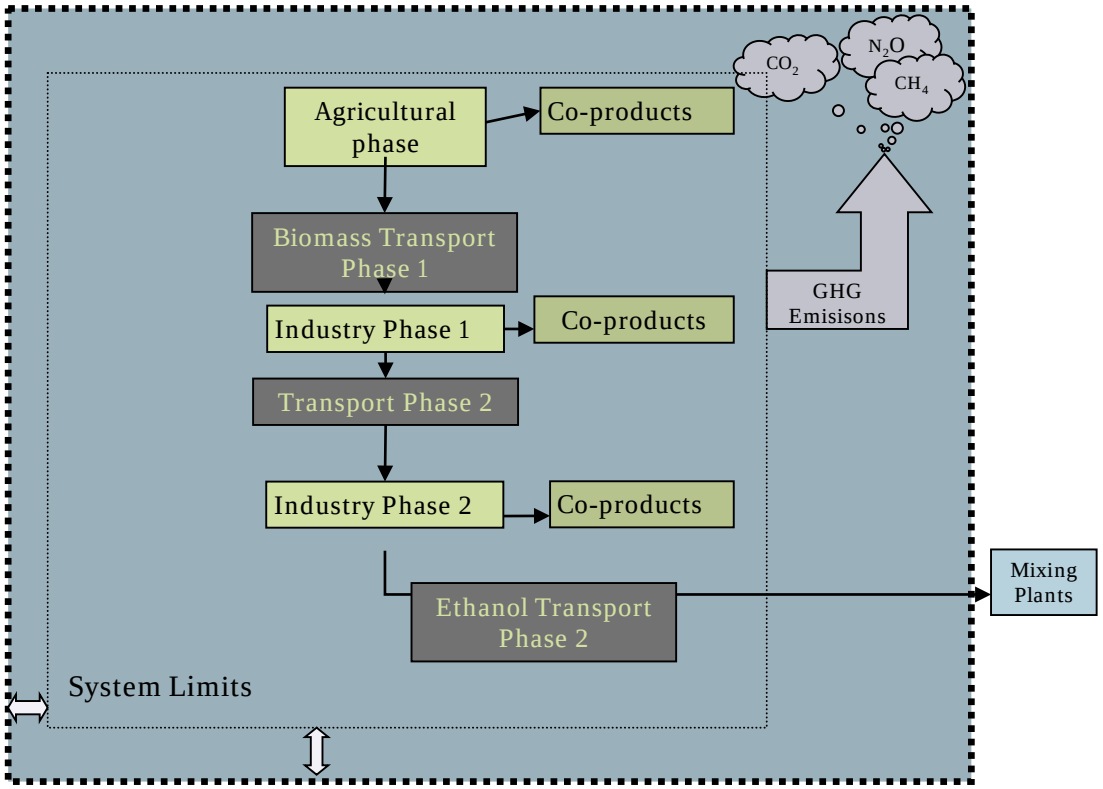
Employments/TJ

Land use indicator (Ius)

ha/GJ

Methodology (1)

- For air and energy indicators (Ia, Ie), EU Dir-RES was applied. Frontiers of the system



- Emission Allocations by energy content.

Methodology (2)

- Water Use (Iua): irrigation water (blue water) calculation using CROPWAT software and its weather database CLIMWAT. Water allocated by energy content. (m3/GJ)

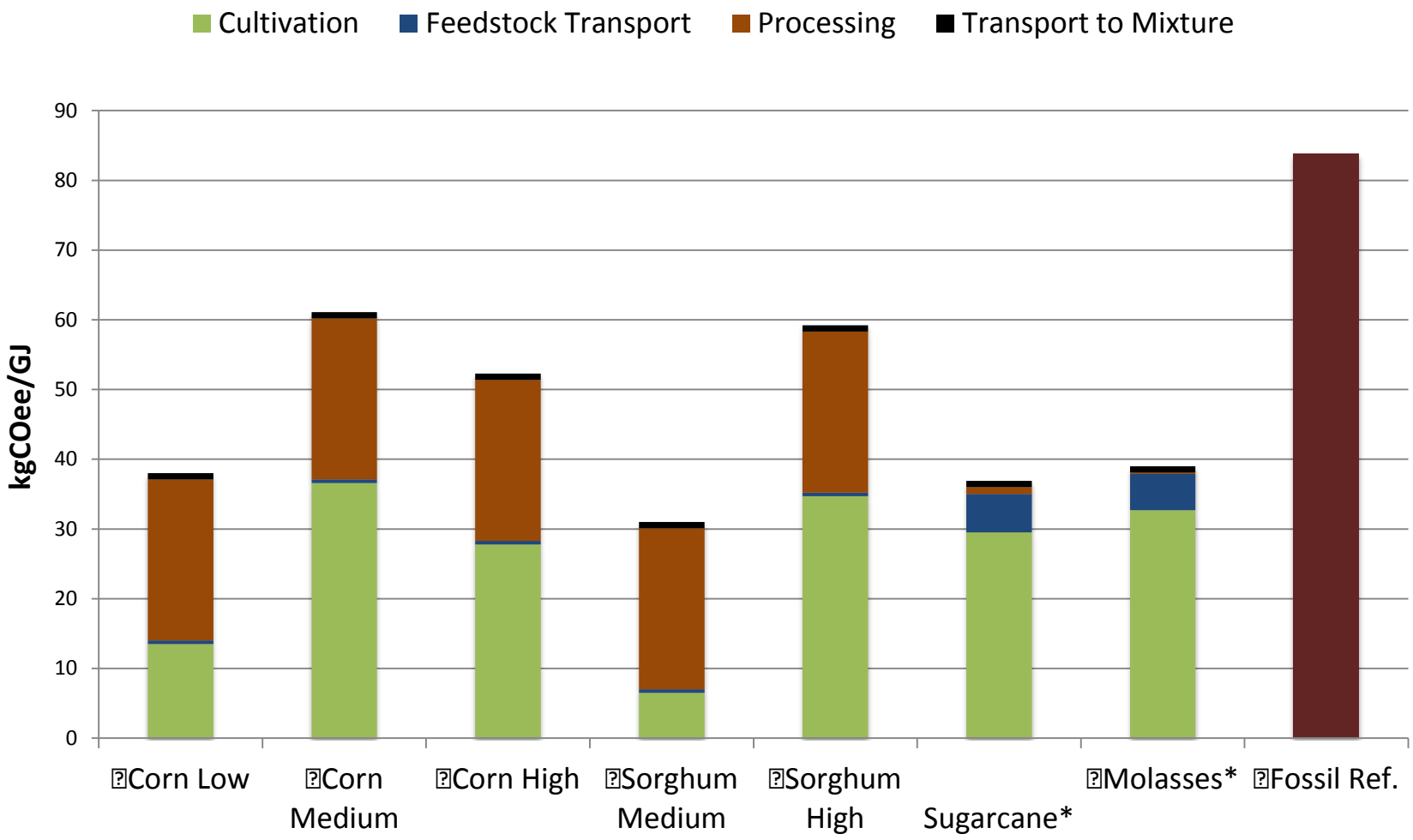
- Land Use (Ius):(crop yield X factory yield X ethanol LHV)$^{-1}$ (ha/GJ)

Methodology (3)

- Economic Indicator (Iec): Net Present Value calculation. Input biomass production costs were considered, in the industrial phase: investment, O&M costs, fuel costs, electricity costs. Benefits from co-product sales. (USD/L)

- Social Indicator (Is): direct hours of employment were calculated for biomass production, transport, and industrial transformation. 1 job = 1800 hours/year. (Jobs/TJ)

Ia Life cycle assessment of greenhouse gas emissions

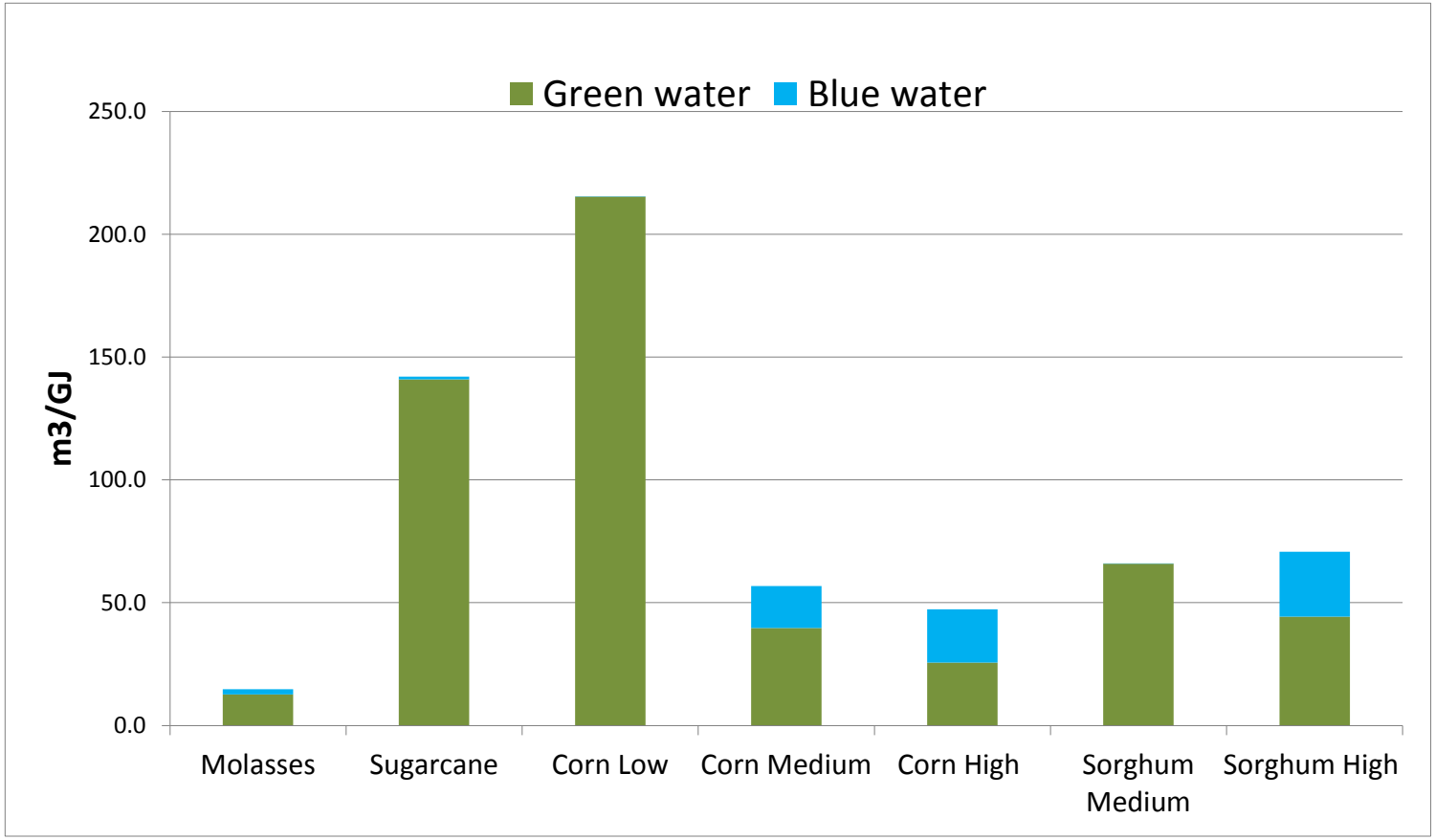


Source: García et al. 2014

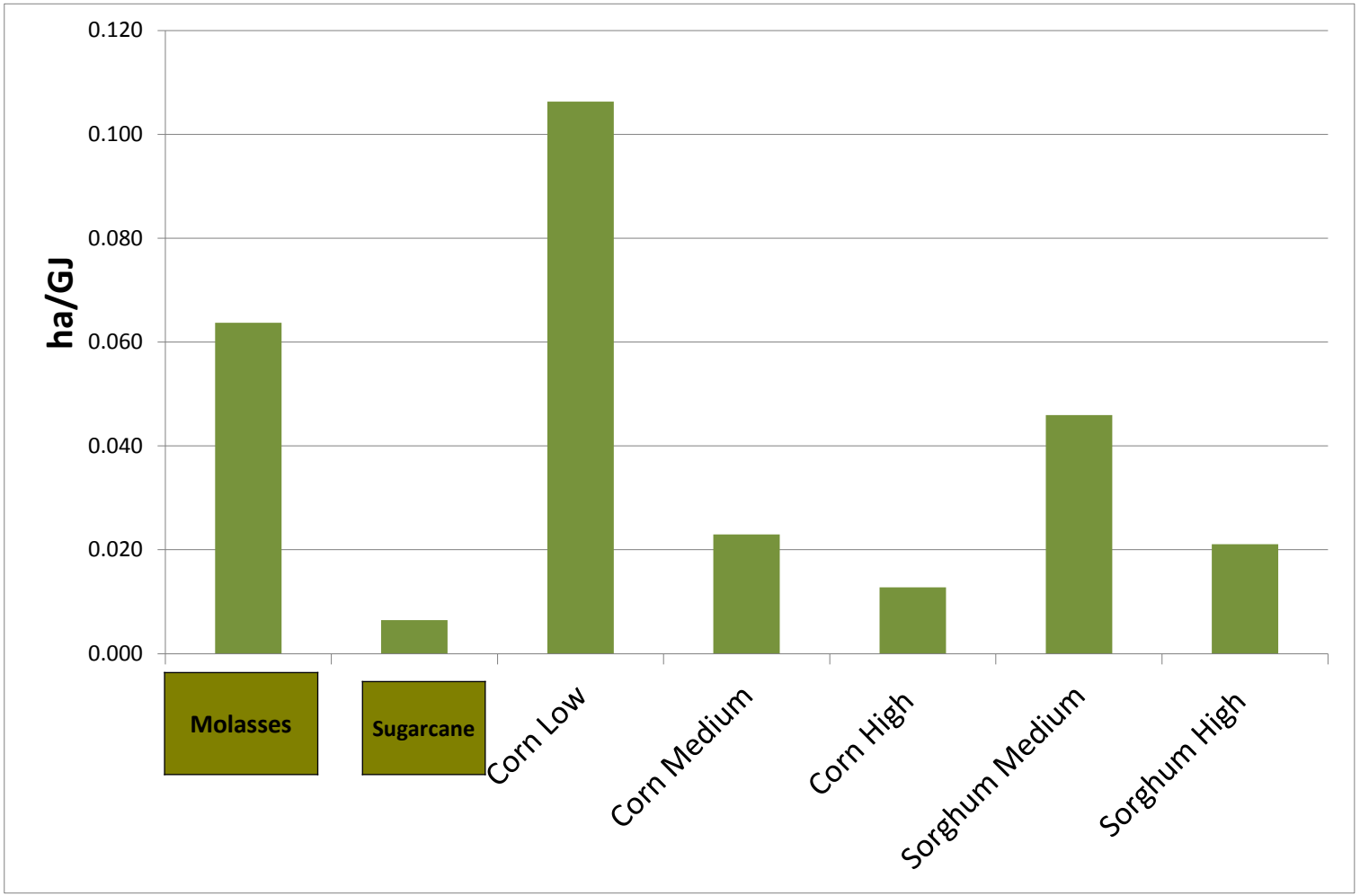
Ie (EROEI)

	Molasses	*Sugarcane*	*Corn Low*	*Corn Medium*	*Corn High*	*Sorghum Medium*	*Sorghum High*
GJ ethanol/ GJ fossil	**4.4**	**4.8**	**2.7**	**2.1**	**2.2**	**2.9**	**2.1**

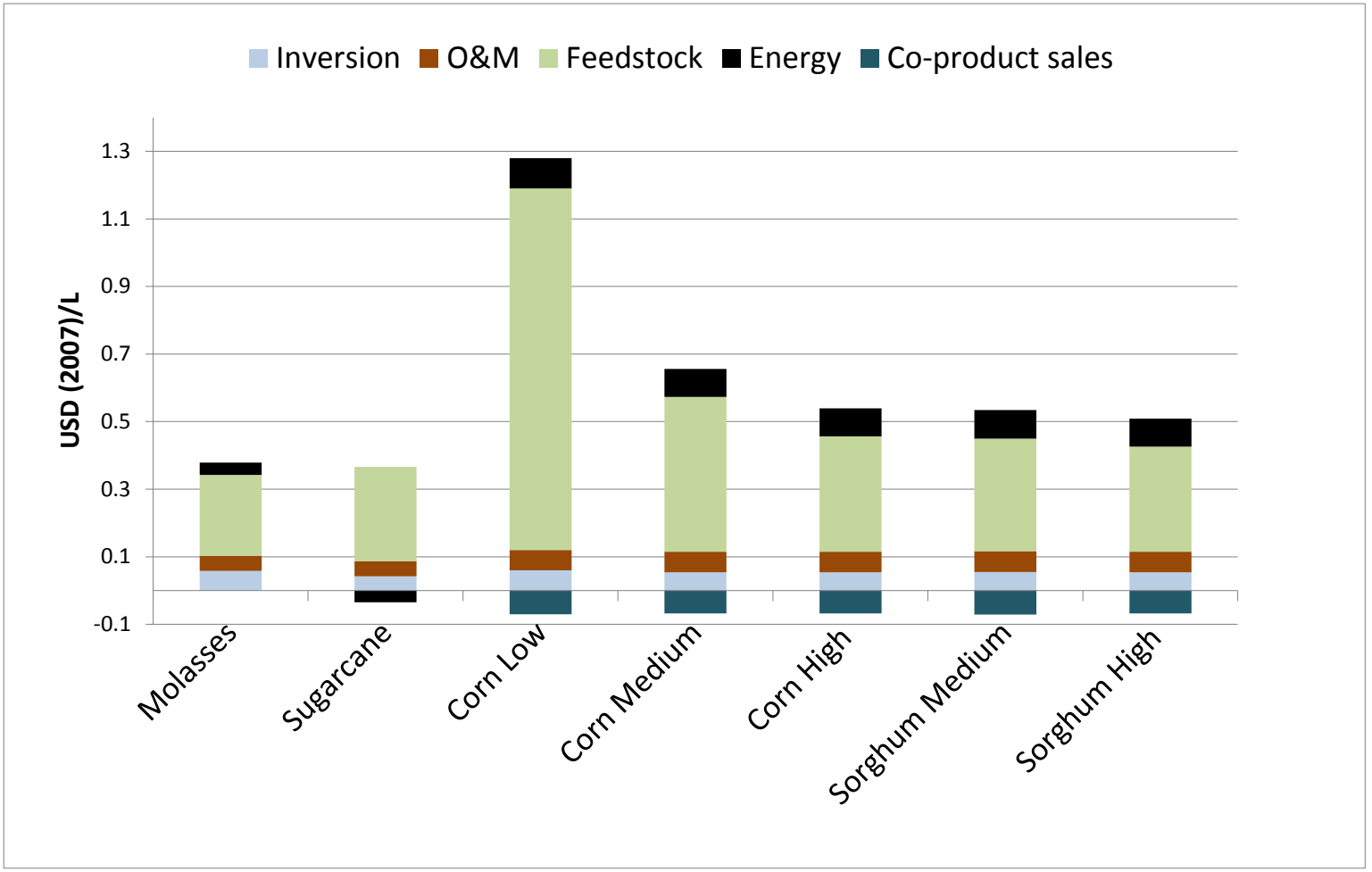
Iua (Water consumption)



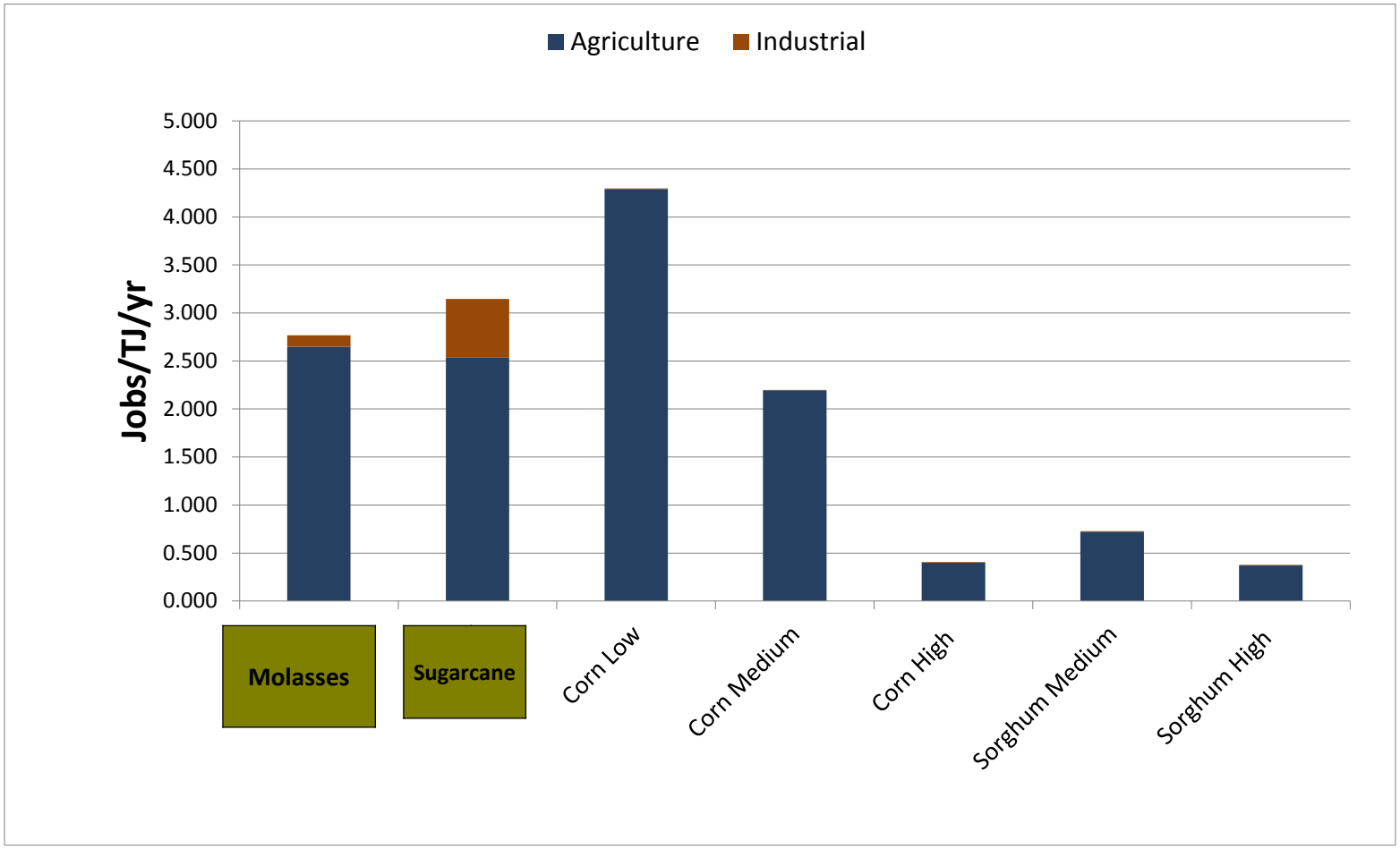
Ius (Land Use)


0.120
0.100
0.080
0.060
0.040
0.020
0.000
ha/GJ
Molasses
Sugarcane
Corn Low
Corn Medium
Corn High
Sorghum Medium
Sorghum High

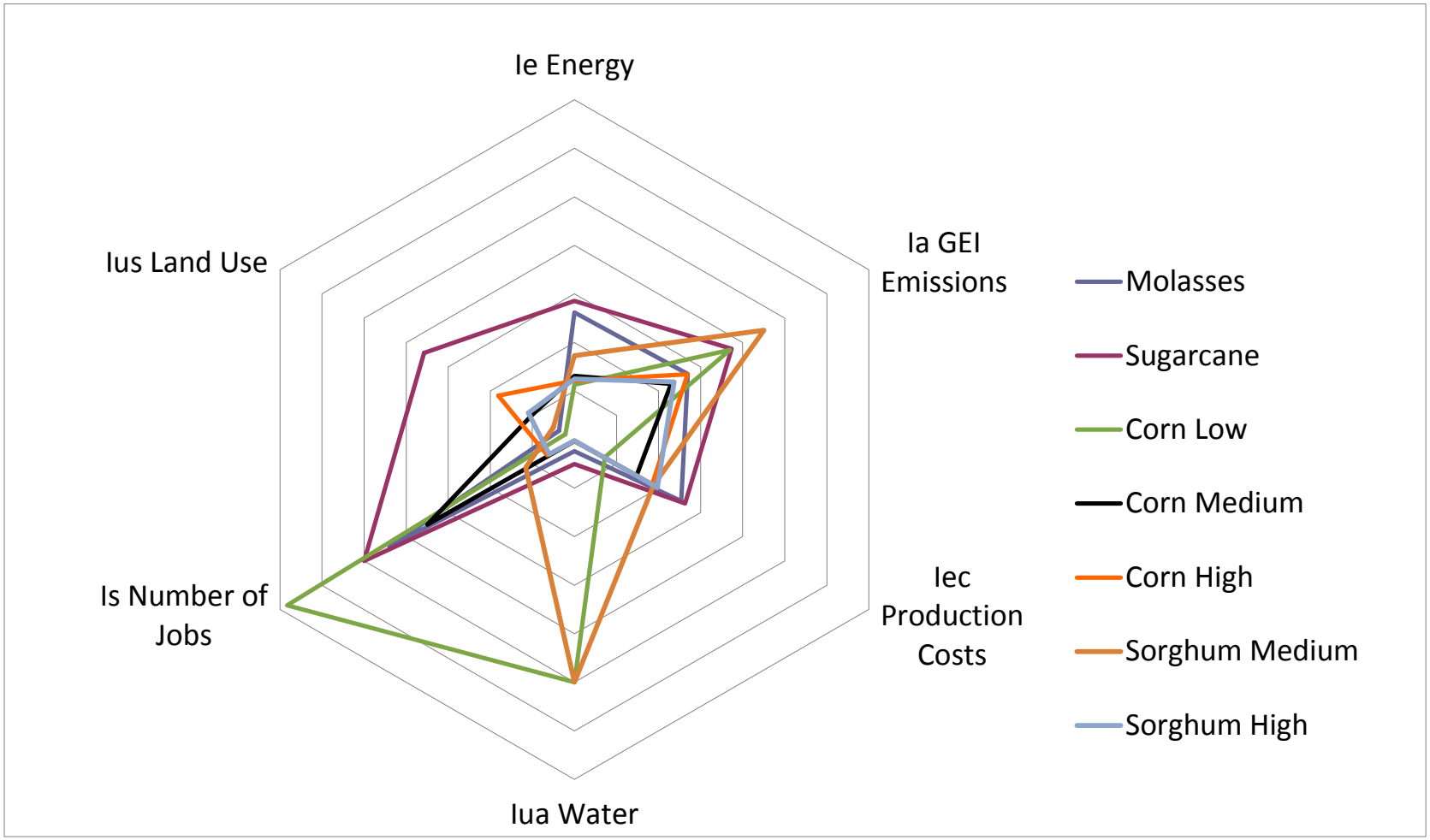
Iec (Production Costs)



Is (Jobs Generated)



Indicators

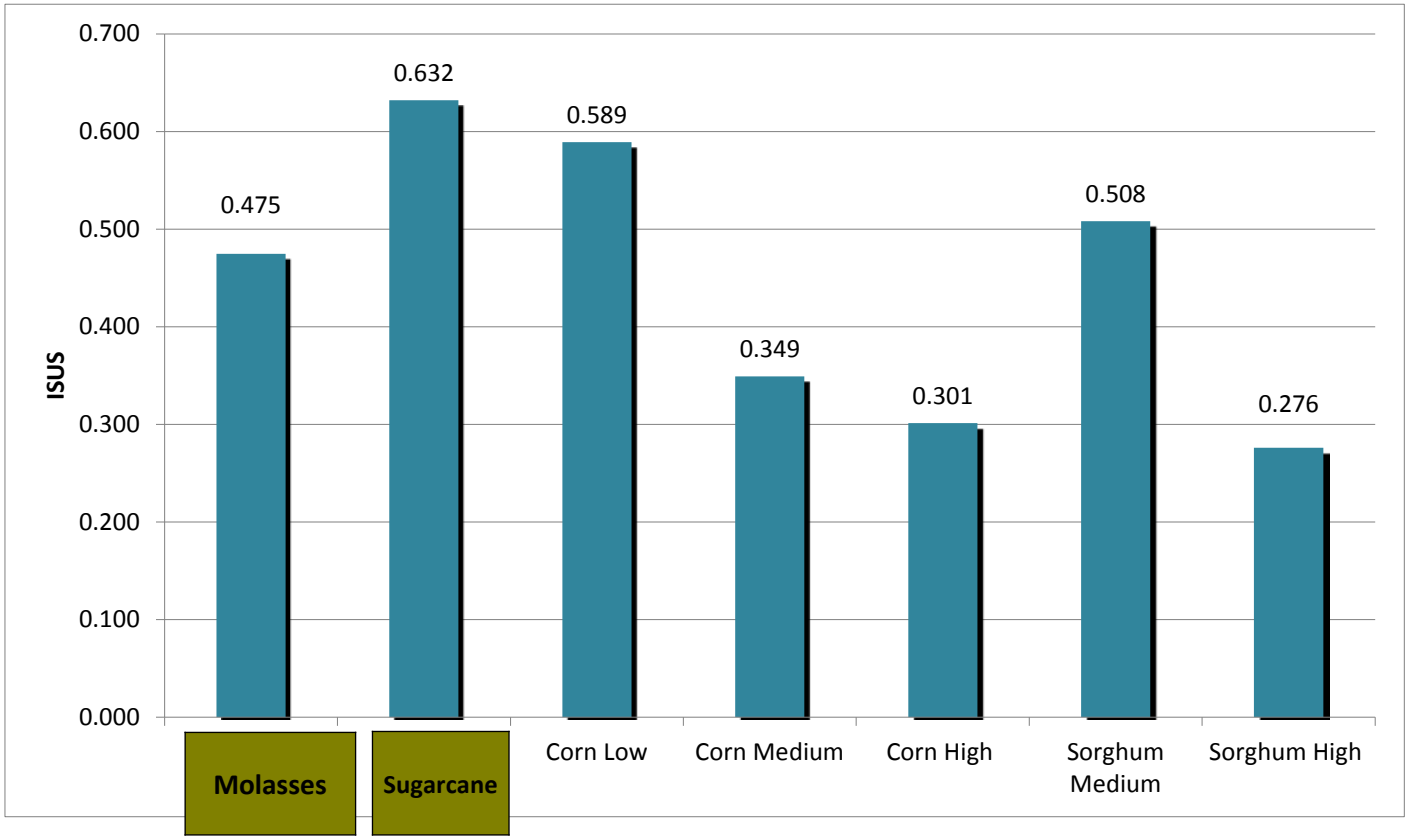


The greater the area covered by each of the options the more sustainable it is.

Sustainability Index (Results)

$$I_{SUS} = \sum_{c} w_c x_c$$

	Ia	Iec	Is	Ie	Iua	Ius
Weighting factor *w*	**23%**	**22%**	**17%**	**15%**	**12%**	**11%**



Conclusions

- Mexico needs to decrease its gasoline and diesel consumption and imports.
- Mexico has limited land resources, but there is an important potential for biofuel feedstocks, especially sugarcane for ethanol production.
- Ethanol from sugarcane comes out as the best (most sustainable) option for Mexico.

Conclusions

- To improve ethanol sustainability it is necesary to:

- Improve agricultural practices: increase fertilization efficiency, decrease diesel use in field vehicles and machines, increase crop yields, avoid or minimize irrigation.
- Avoid fossil fuels for energy generation in industrial production.
- Promote co-products.

Thank you!

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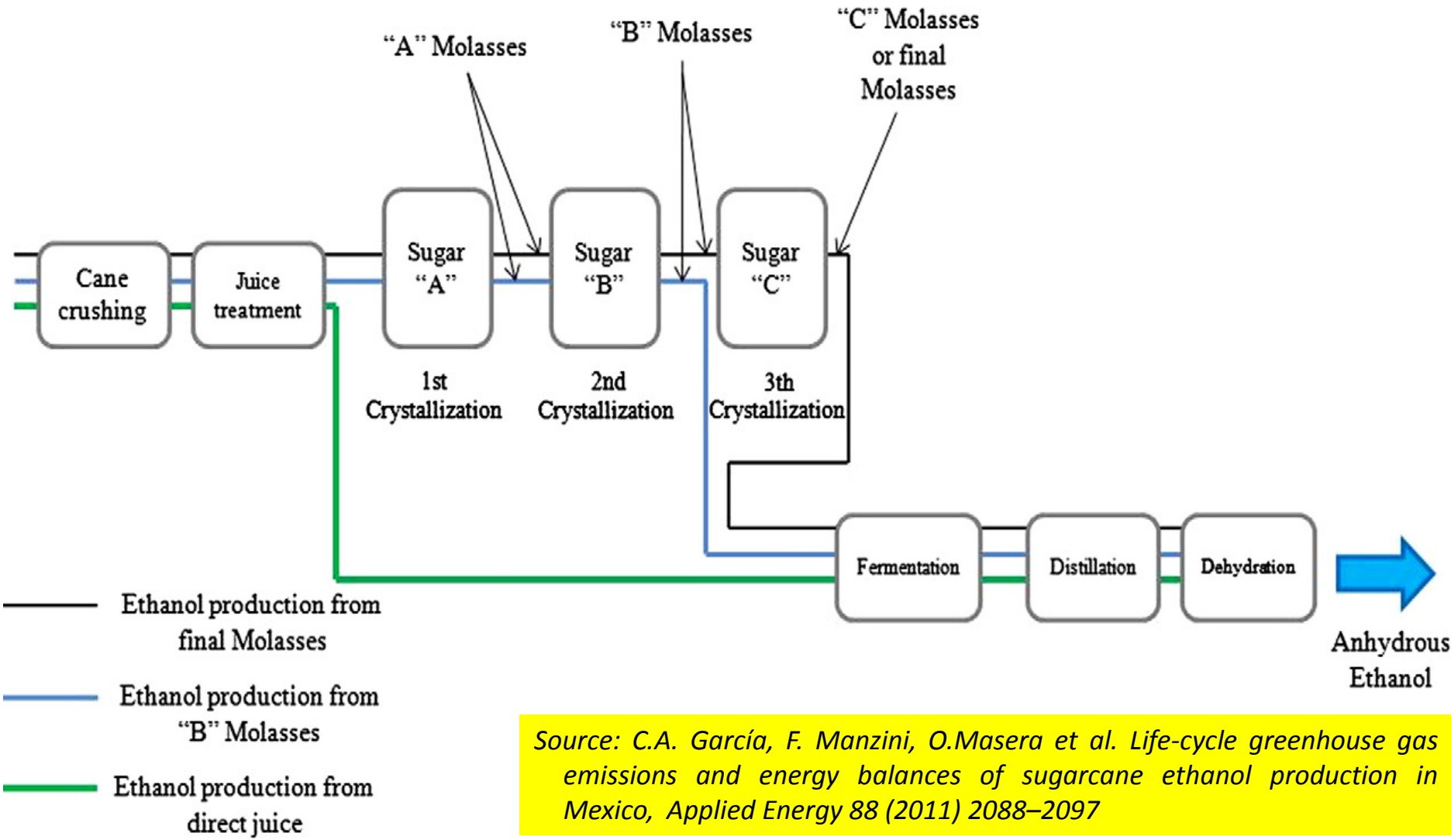
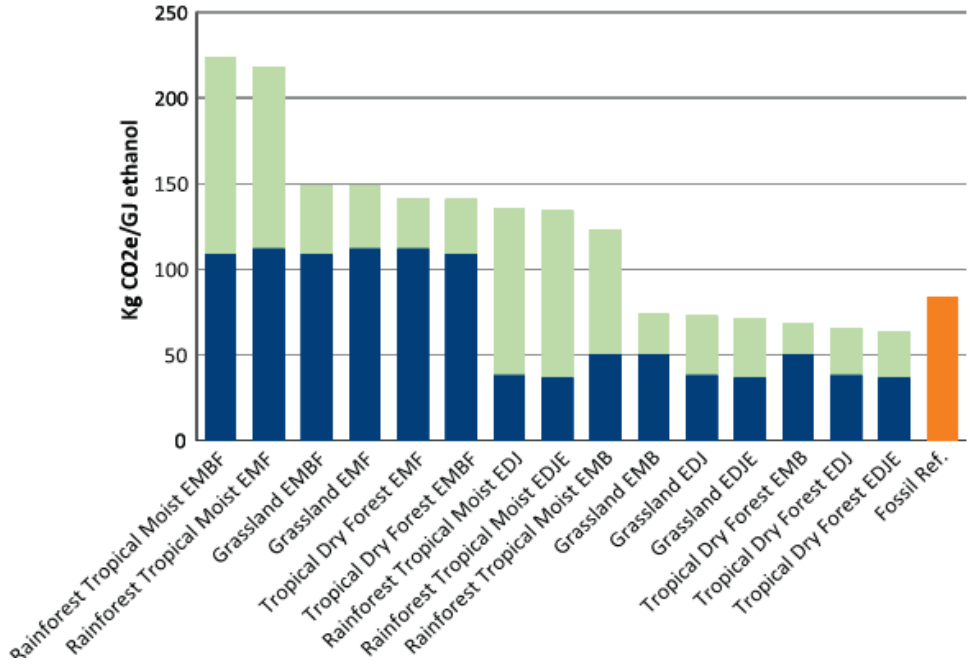
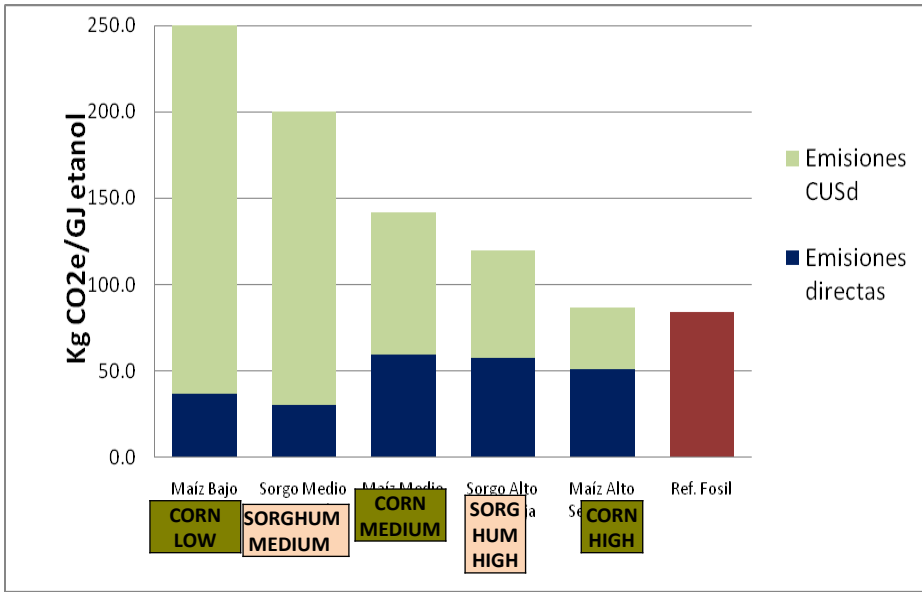
Industrial processes of ethanol production using sugarcane



Source: C.A. García, F. Manzini, O.Masera et al. Life-cycle greenhouse gas emissions and energy balances of sugarcane ethanol production in Mexico, Applied Energy 88 (2011) 2088–2097

Ia (emissions with direct LUC)





EMF: Ethanol C Molasses Fueloil
EMBF: Ethanol B Molasses Fueloil
EMB: Ethanol C Molasses Bagasse
EDJ: Ethanol Direct Juice
EDJE: Ethanol Direct Juice +Electricity