IEA Bioenergy
Technology Collaboration Programme

Task 39
IEA Bioenergy

Analyze status of biofuels production and use in non-IEA countries/emerging economies

Brazilian Teams:

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Collaborators:

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November 23, 2020

Specific objectives:

1. Selection of the countries that are considered as emerging economies with a large population and in average lower energy consumption compared to developed countries.
2. Identification of official data source for each country in terms of energy production, energy demand as well as the production of biofuels.
3. Database construction of relevant data (*energy matrix, feedstock availability, the energy expenditure of production, net energy content, energy conversion efficiency, among others*).
4. Identification of possible raw-materials and conversion technologies.
5. Evolve the analysis including sustainability (*Energy and Exergy-based performance indicators*).
6. Evaluate how incentives can alter sustainability and process (*using Renovabio as a case study, sugarcane biorefinery concept*).
7. Generation of periodic reports, and scientific papers.

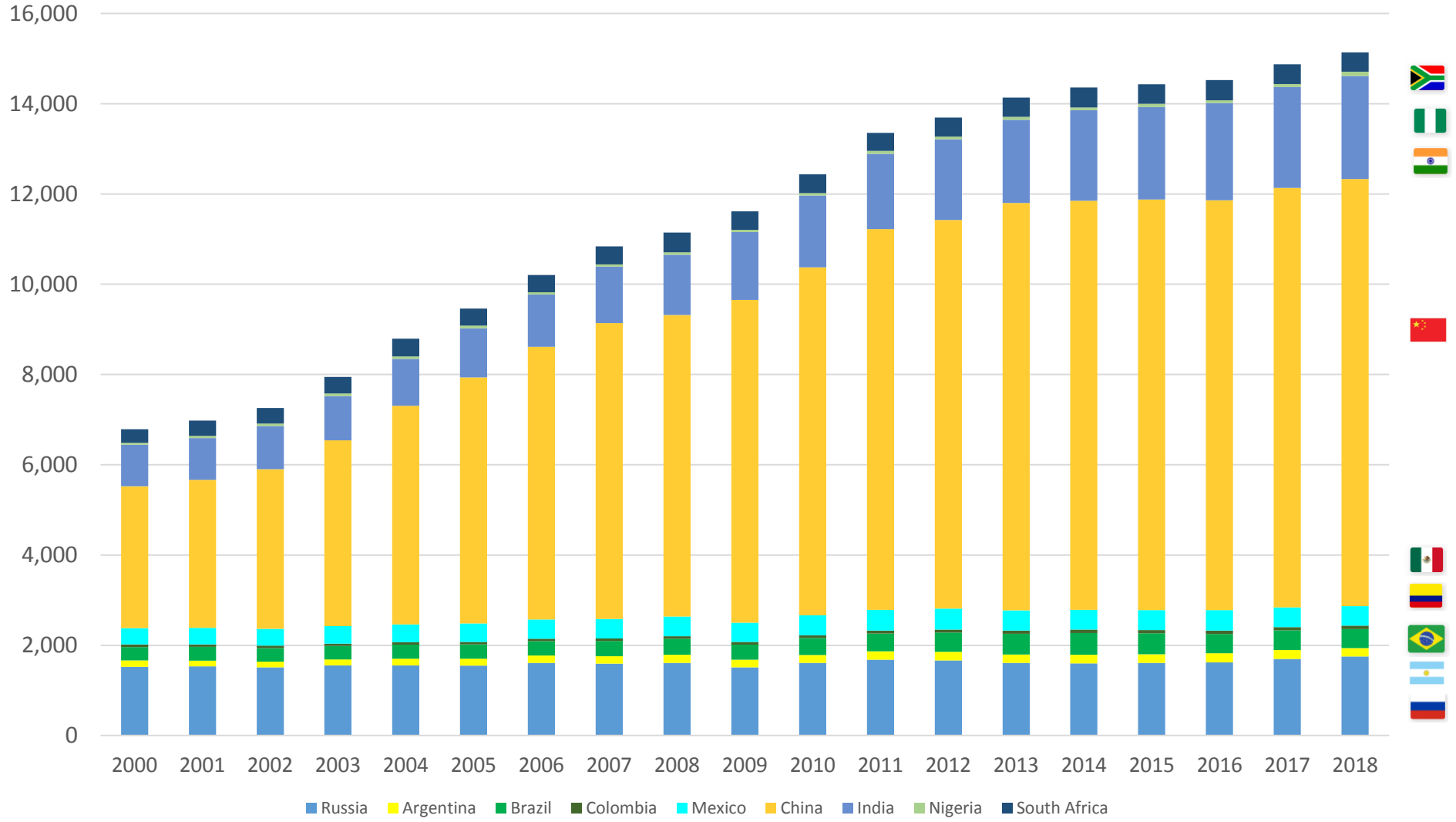
On-going steps

1. Database development	*In progress*
2. Update and expansion of the database of the energy matrix, including feedstock production and use for energy in each of the selected countries	*DONE*
3. Identification of possible raw-materials and conversion technologies in each of the selected countries	*In progress*
4. Evaluation of incentives using the Renovabio program as a case study	*In progress*
5. Generation of periodic reports and scientific papers	*In progress*

Selected countries | Data sets

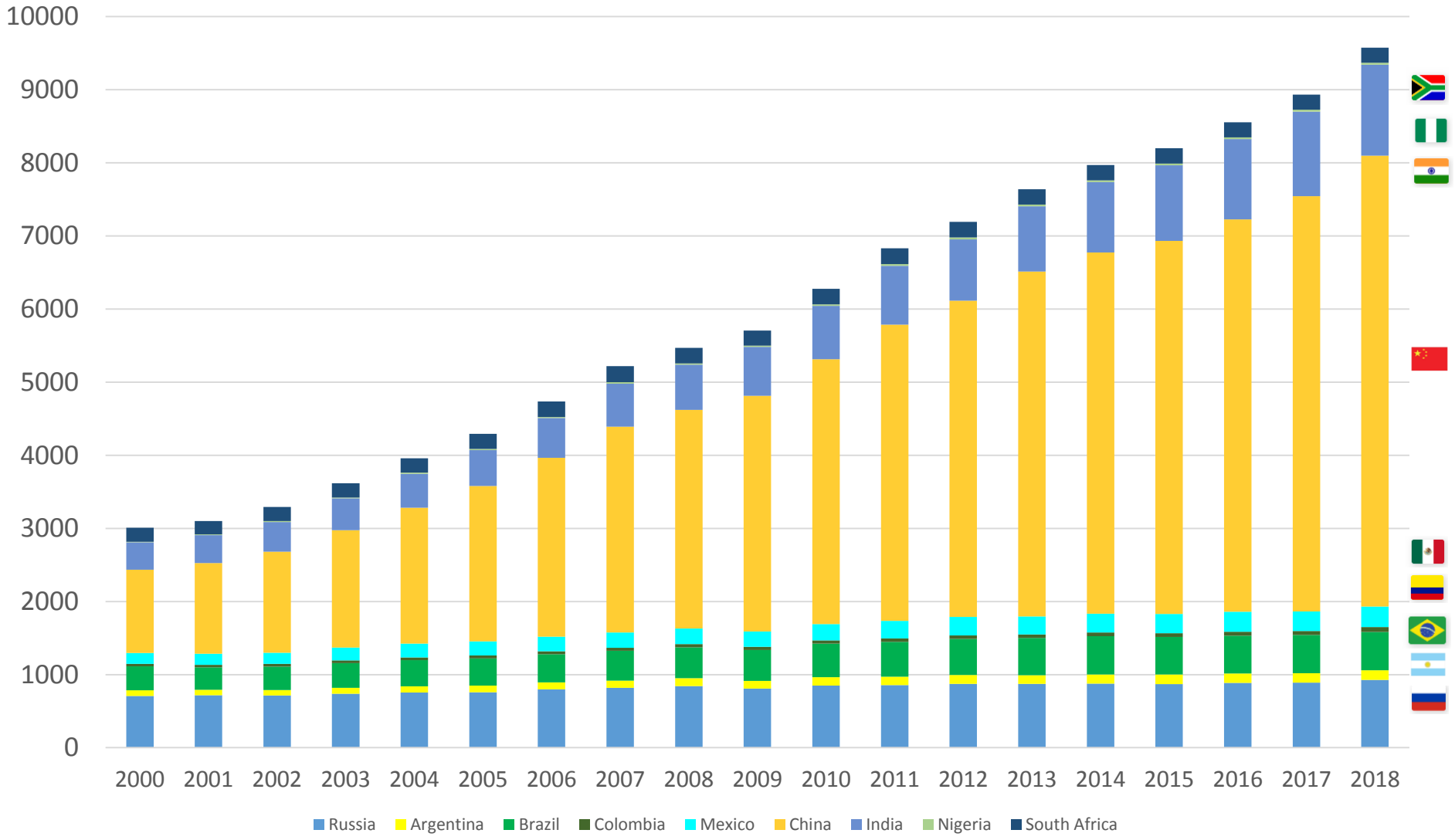
		Raw materials
Latin America		
Brazil		Sugarcane; Corn; Bagasse; Soy oil
Argentine		Corn; Molasses
Colombia		Sugarcane; Crude Palm Oil
Mexico		Sugarcane, Jatropha, Castor, Sunflower, Soy and grain sorghum
Africa		
South Africa		Soya; Canola; Sunflower; Sugarcane; Sugar beet
Nigeria		Sugarcane, cassava, plant seed and waste materials.
Asia		
India		Sugarcane, Sugar beet, Sweet Sorghum, Corn, Cassava, Algae.
China		Kernals; Cassava; Sweet Sorghum; Cellulosic Biomass
Thailand		Sugarcane; Cassava; Molasses
Malaysia		Crude Palm Oil
Europe		
Russia		Fuel pellets, rapeseeds, and rapeseed oil

CO_2 emissions from fuel combustion ($MtCO_2$)



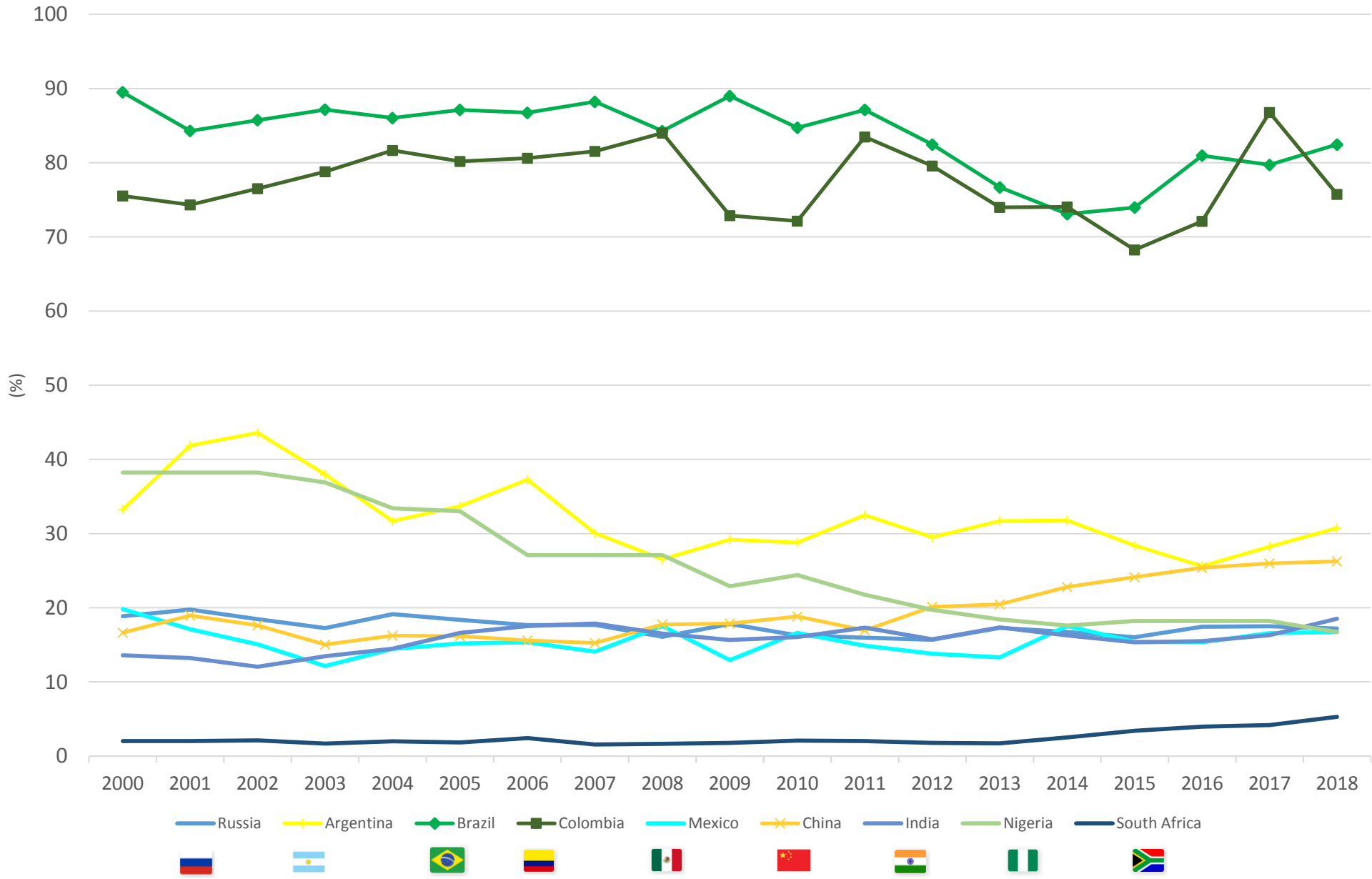
Based on Enerdata, Global Energy Statistical Yearbook 2019

Electricity domestic consumption (TWh)



Based on Enerdata, Global Energy Statistical Yearbook 2019

Share of renewables in electricity production (%)



Based on Enerdata, Global Energy Statistical Yearbook 2019

Key performance indicators (KPIs)

Total Energy Production (Mtoe)
Electricity domestic consumption (TWh)
Share of renewables in electricity production (%)
CO_2 emissions from fuel combustion ($MtCO_2$)
c_{NR}: unit exergy cost of non-renewable (kJ/kJ)
c_R: unit exergy cost of renewable (kJ/kJ)
c_T: unit exergy cost total (kJ/kJ)
mCO_2: CO_2 emissions (gCO_2/kWh)
Renewability exergy index
Global energy and exergy efficiency
Carbon Efficiency
Fuel selling price

IEA Bioenergy

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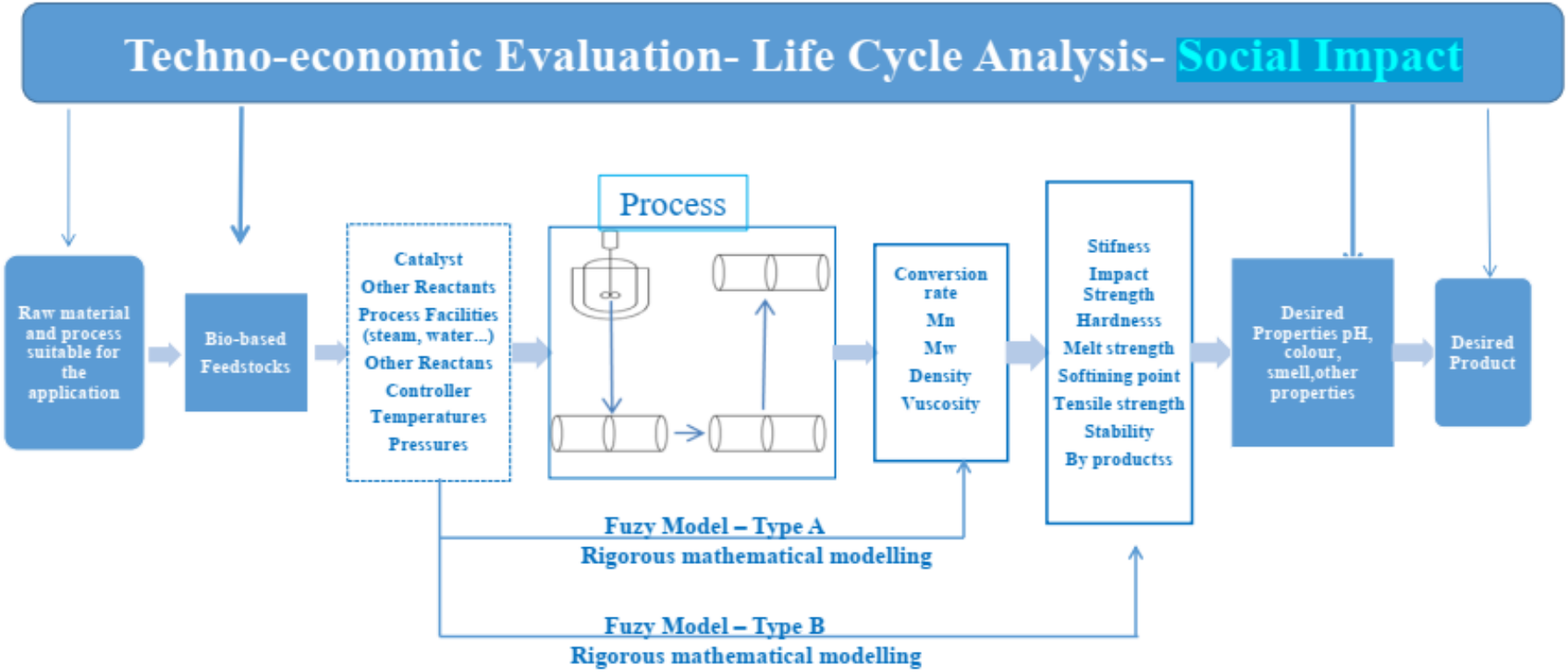
General Methodology for Sustainable Products



Redesign of the feedstocks (fermentation ? Crops ?) and conversion/separation process depending on final application. **Capital and Operating costs, Emission Inventory, Exergy Analysis**

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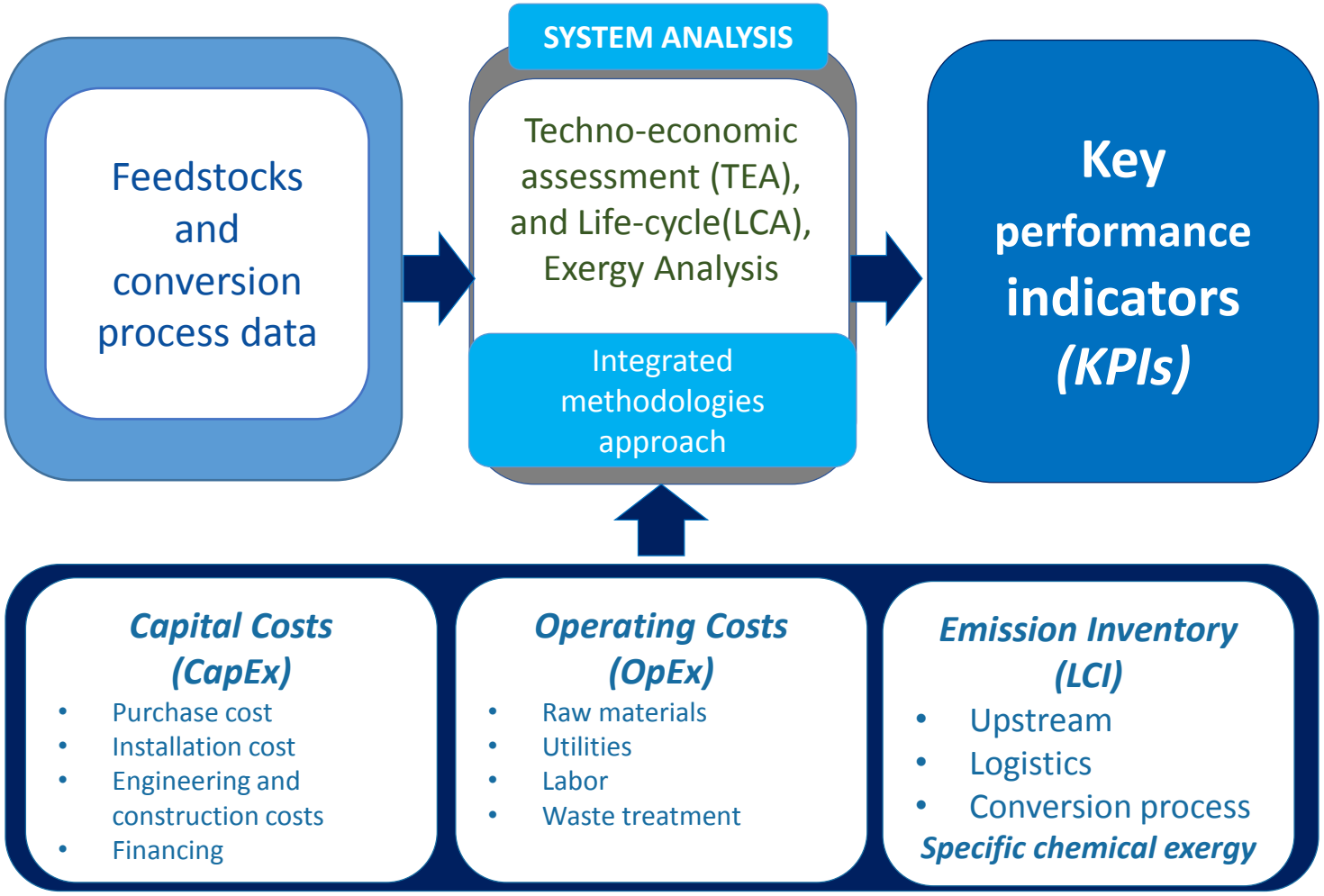
Methodology

SCOPE: *Developing Countries with large populations and high energy demand.*



TOOLS FOR DEVELOPMENT

Excel

python™

OPENLCA

Methodology

Comparative Energy Balance to Crop Choice as Feedstock (e.g. Ethanol)

PROCESS Feedstock	**Corn[1]**	**Switchgrass[1]**	**Sugar cane[2]**
Energy unit	**(GJ/ha.yr)**	**(GJ/ha.yr)**	**(GJ/ha.yr)**
Crop production energy consumption	**18.9**	**17.8**	**13.9**
Biomass Energy	**149.5[3]**	**220.2**	**297.1[4]**
Agricultural energy ratio	**7.9**	**12.3**	**21.3**
Ethanol production energy consumption	**47.9**	**10.2**	**3.4**

1- Source: ORNL, 2- Source: Copersucar/UNICAMP, 3-No credit for corn stover, 4- No credit for sugar cane leaves

How to evaluate if metabolic improvement is viable: Theoretical Photosynthesis Production Capacity (TPPC) compared to observed production

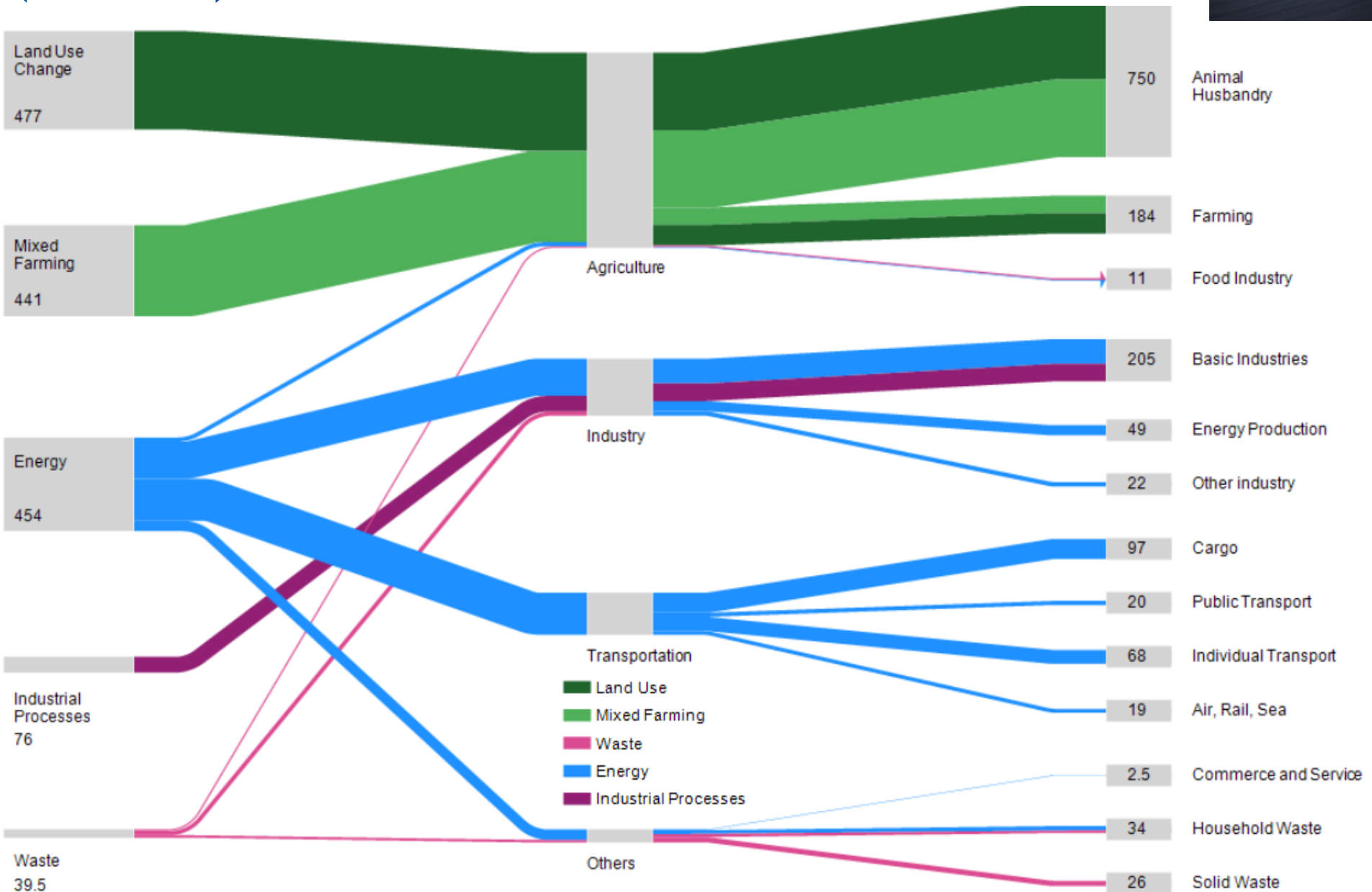
For sugar cane TPPC= 386 ton/hay and the observed production capacity is 85 ton/hay (*Moore et. al, 2013, Souza Mendes et. al 2015*)

For sugar cane ethanol - 9-14 liters renewable energy/liter fossil energy

Oil - Each unit of energy invested to produce oil in the 1940s yielded the equivalent of 110 energy units (1 to 100) Nowasdays - depending upon the oil field 1-10

(*Maciel Filho, 2014*)

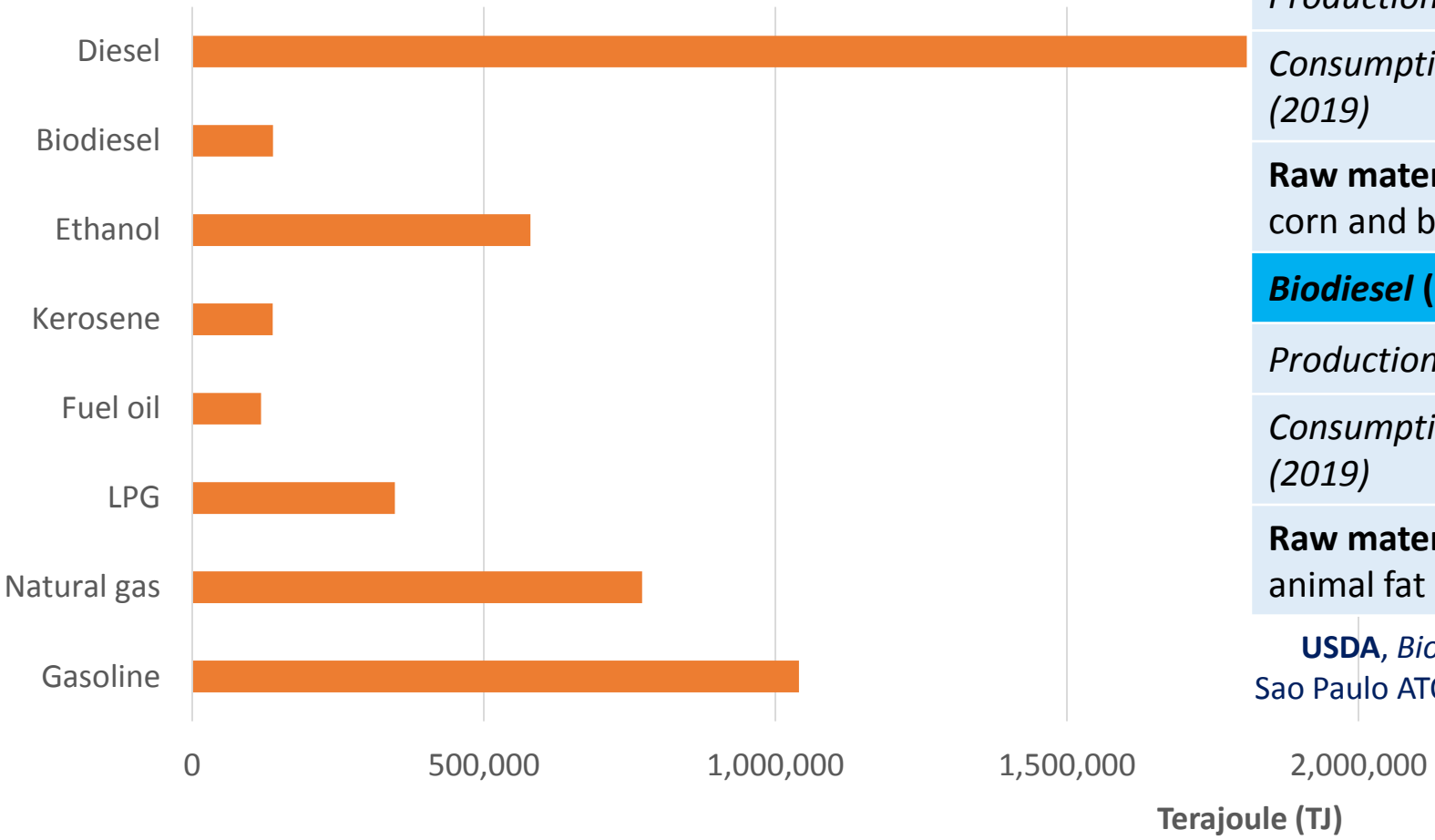
Ex. *GHG emissions of a country by sector (Mt CO2e)*



STATUS QUO BIOFUEL PRODUCTION

BRAZIL

Final energy consumption (2019)



Bioethanol **(Million liters)**	
Production (2019)	*34,437*
Consumption (2019)	*32,848*
Raw materials: Sugarcane, corn and bagasse	

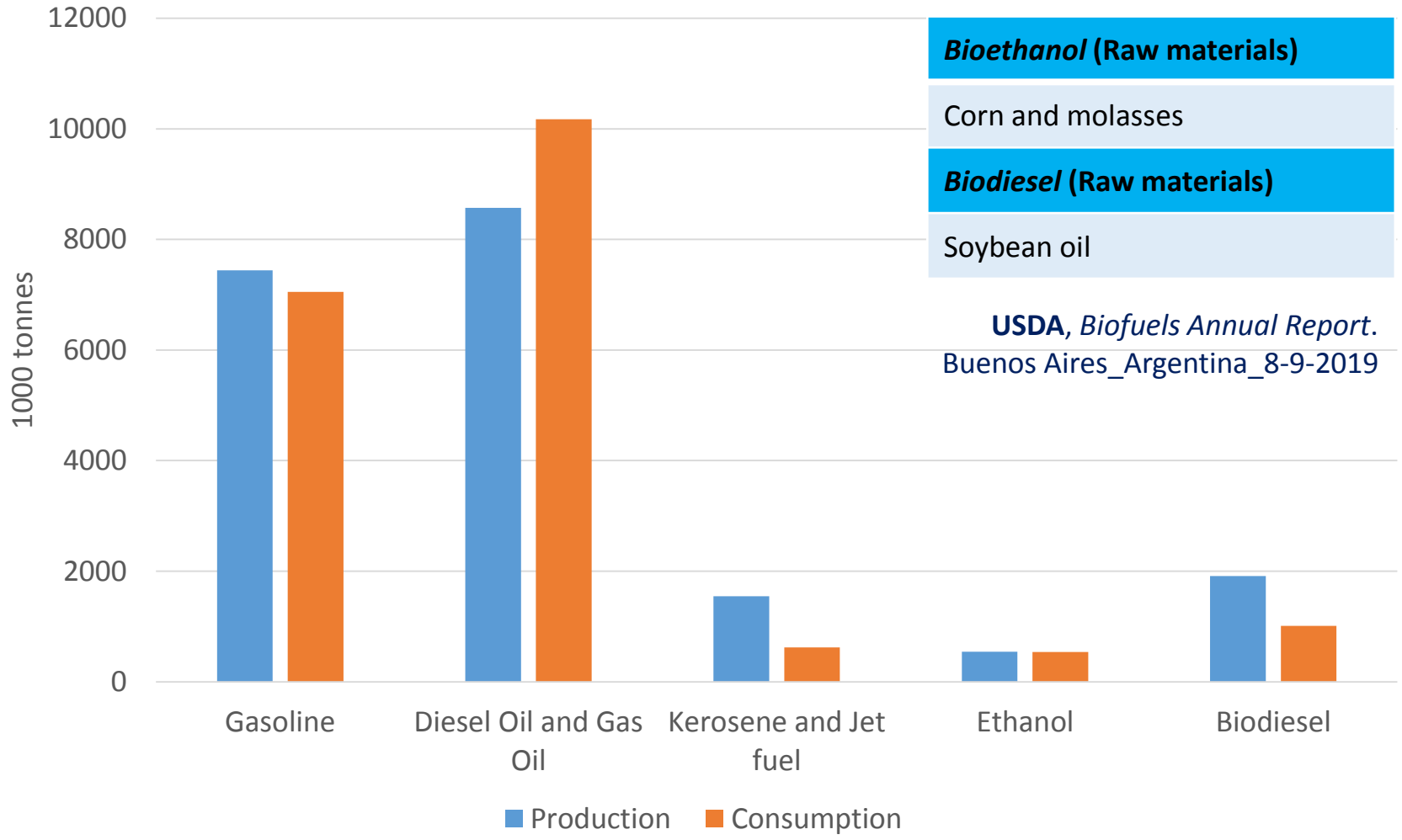
Biodiesel **(Million liters)**	
Production (2019)	5,925
Consumption (2019)	5,921
Raw materials: Soy oil and animal fat (tallow)	

USDA, *Biofuels Annual Report*. Sao Paulo ATO_Brazil_08-03-2020

BRAZILIAN ENERGY BALANCE, BEN 2020
Ministry of Mines and Energy – MME
http://epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/balanco-energetico-nacional-ben

ARGENTINE

(2019)



Bioethanol **(Raw materials)**

Corn and molasses

Biodiesel **(Raw materials)**

Soybean oil

USDA, *Biofuels Annual Report*. Buenos Aires_Argentina_8-9-2019

Tons of oil equivalent to joules conversion factor

1 ton of oil equivalent is equal to 41868000000 joules

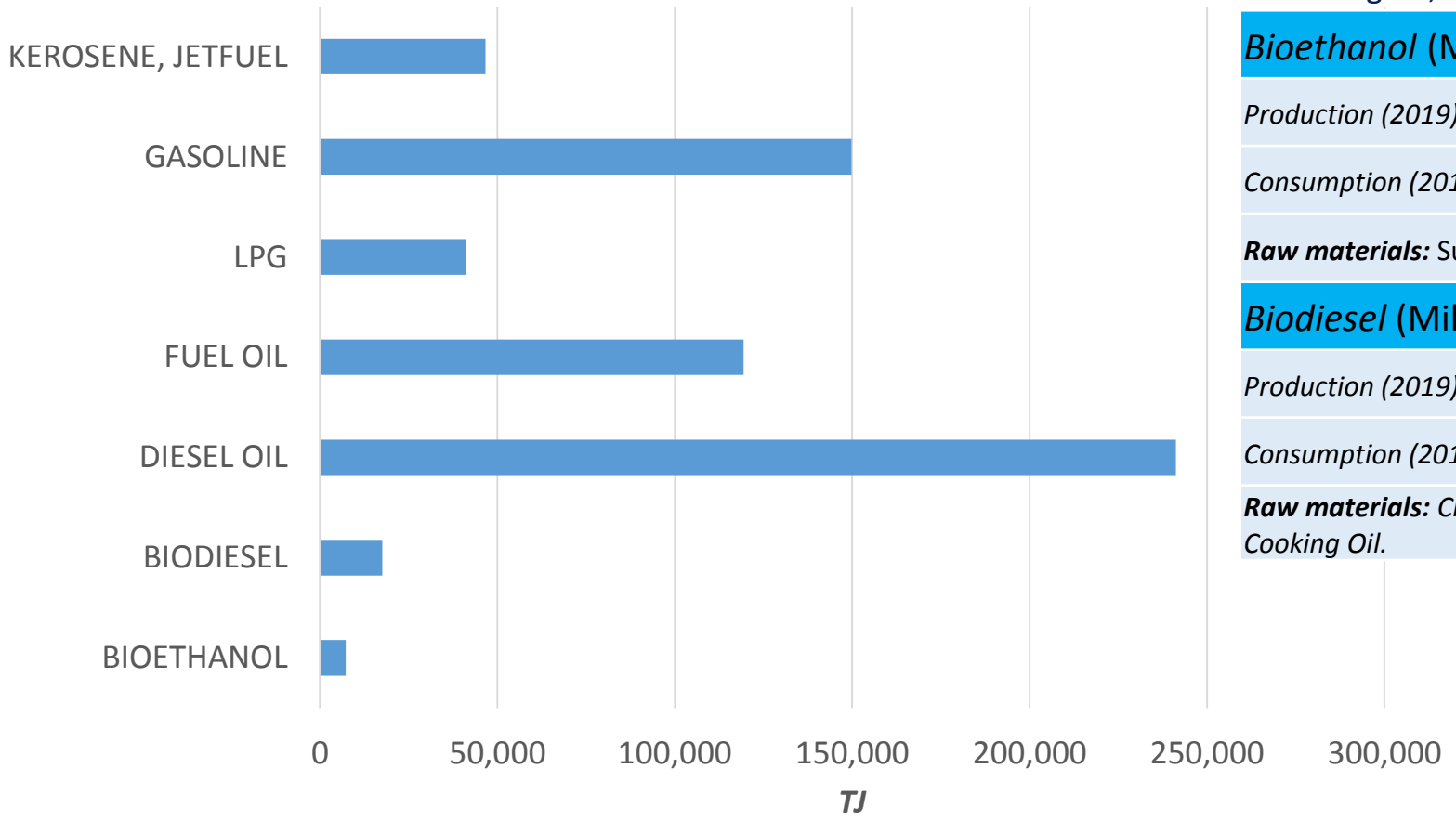
ARGENTINE ENERGY BALANCE, 2019

Ministry of Energy

https://www.argentina.gob.ar/energia/hidrocarburos/balances-energeticos

COLOMBIA

USDA, *Biofuels Annual Report*.
Bogota, Colombia_07-06-2020



Bioethanol (Million Liters)	
Production (2019)	*450*
Consumption (2019)	*710*

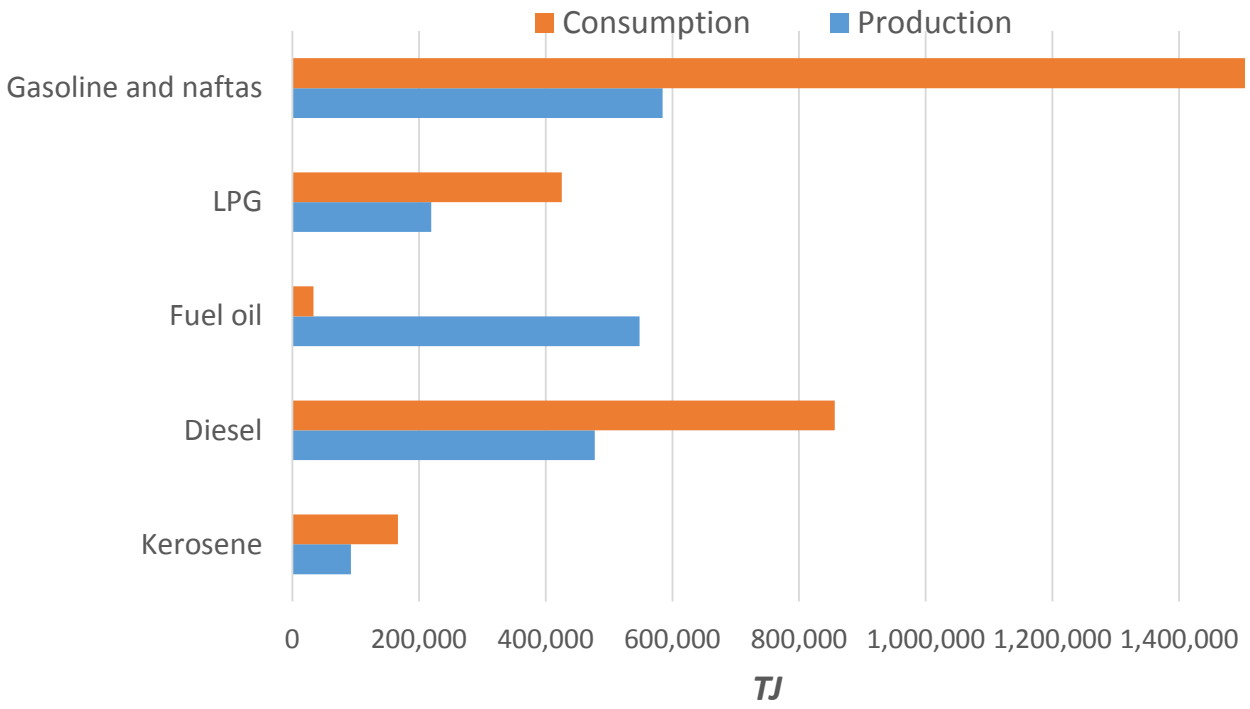
Raw materials: Sugarcane.

Biodiesel (Million Liters)	
Production (2019)	*610*
Consumption (2019)	*605*

Raw materials: *Crude Palm Oil and Used Cooking Oil.*

Colombian Energy Balance, 2017
UPME
http://www1.upme.gov.co/InformacionCifras/Paginas/BECOENERGTICO.aspx

MEXICO



Red Mexicana de Bioenergia and *CEDRSSA*, 2020

Bioethanol (Million Liters)	
Production (2019)	*144*
Consumption (2019)	*320*

Raw materials:
Sugarcane and grain sorghum.

Biodiesel (Million Liters)	
Production (2019)	*4.2*
Consumption (2019)	*6.8*

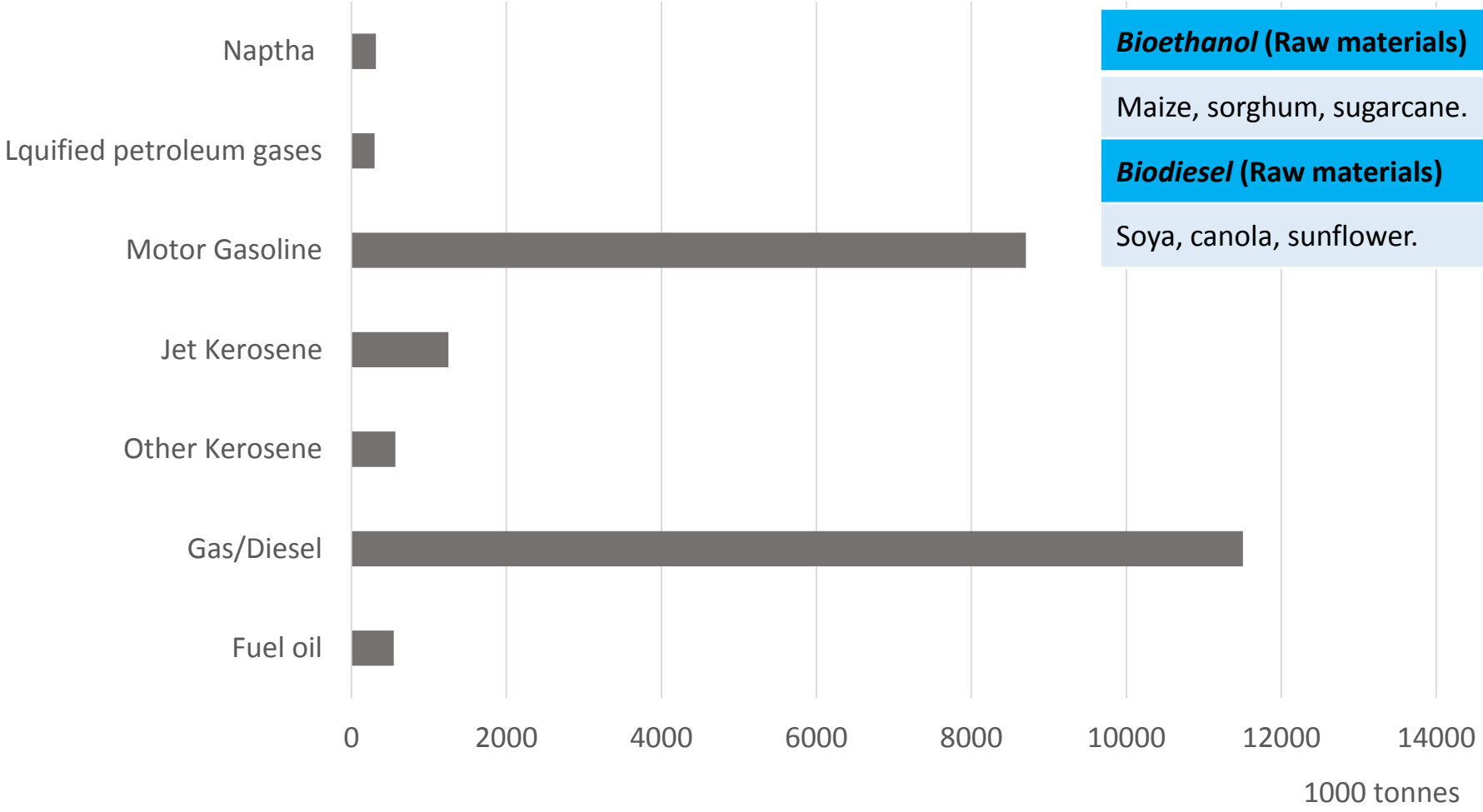
Raw materials:
Jatropha, Castor, Canola, Sunflower, Coconut, Palm, Soy and Animal fat.

Mexican Energy Balance, 2018
SIE - Sistema de Información Energética
http://sie.energia.gob.mx/

SOUTH AFRICA

(2018)

Stafford et al_2019



Bioethanol **(Raw materials)**
Maize, sorghum, sugarcane.
Biodiesel **(Raw materials)**
Soya, canola, sunflower.

Tons of oil equivalent to joules conversion factor

1 ton of oil equivalent is equal to 41868000000 joules

South Africa - The International Energy Agency
https://www.iea.org/countries/South Africa/

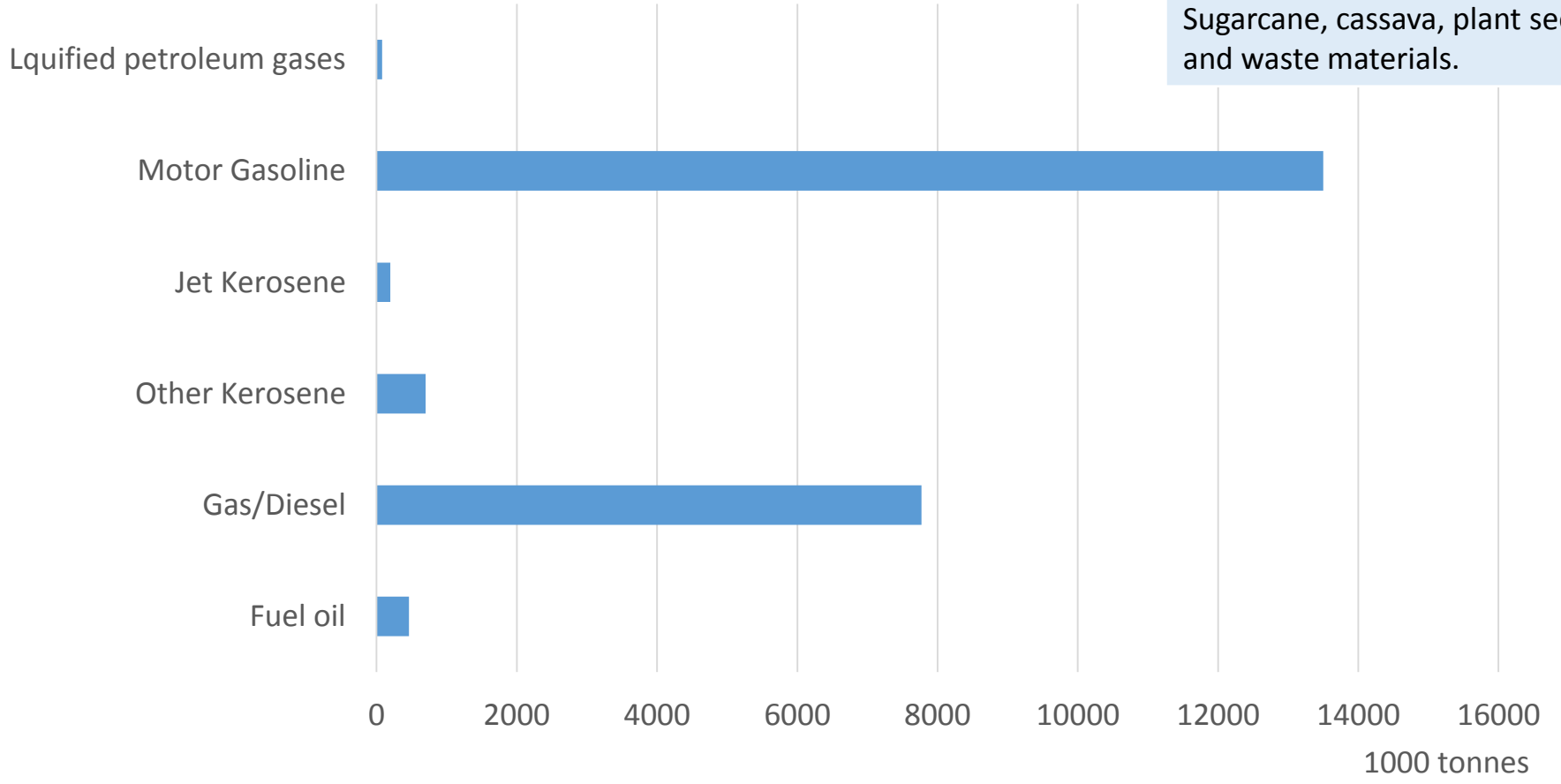
NIGERIA

(2018)

Adewuyi_2020

Bioethanol and Biodiesel
(Raw materials)

Sugarcane, cassava, plant seed and waste materials.

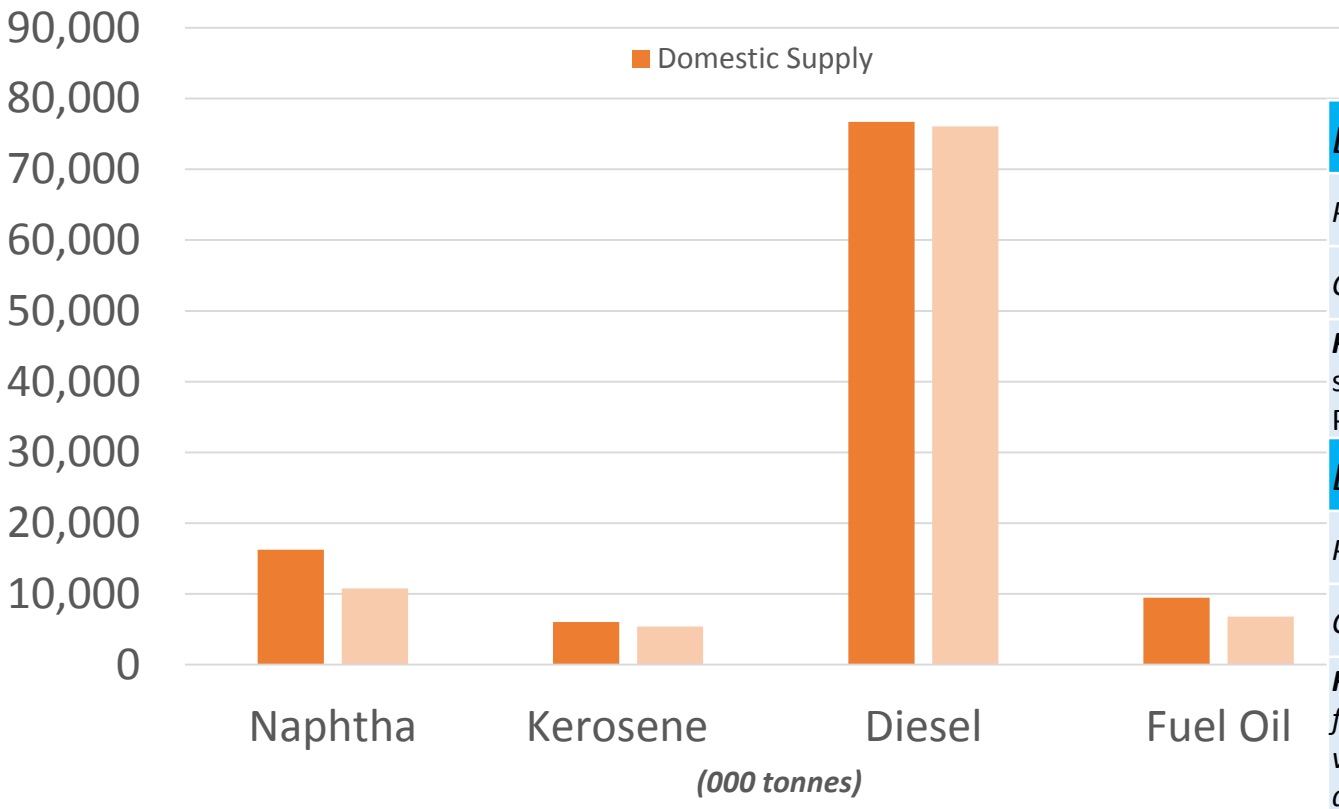


Tons of oil equivalent to joules conversion factor

1 ton of oil equivalent is equal to 41868000000 joules

Nigeria - The International Energy Agency
https://www.iea.org/countries/Nigeria/

INDIA



Energy Commodity Balance for the year 2016-17
Ministry of Power - India
https://powermin.nic.in/

USDA, *Biofuels Annual Report*.
New Delhi_India_07-06-2020

Bioethanol (Million Liters)	
Production (2019)	*2,552*
Consumption (2019)	*3,370*

Raw materials: Sugarcane, Sugar beet, sweet Sorghum, Corn, Cassava, Rotten Potatoes, Algae and Cellulosic materials.

Biodiesel (Million Liters)	
Production (2019)	*230*
Consumption (2019)	*185*

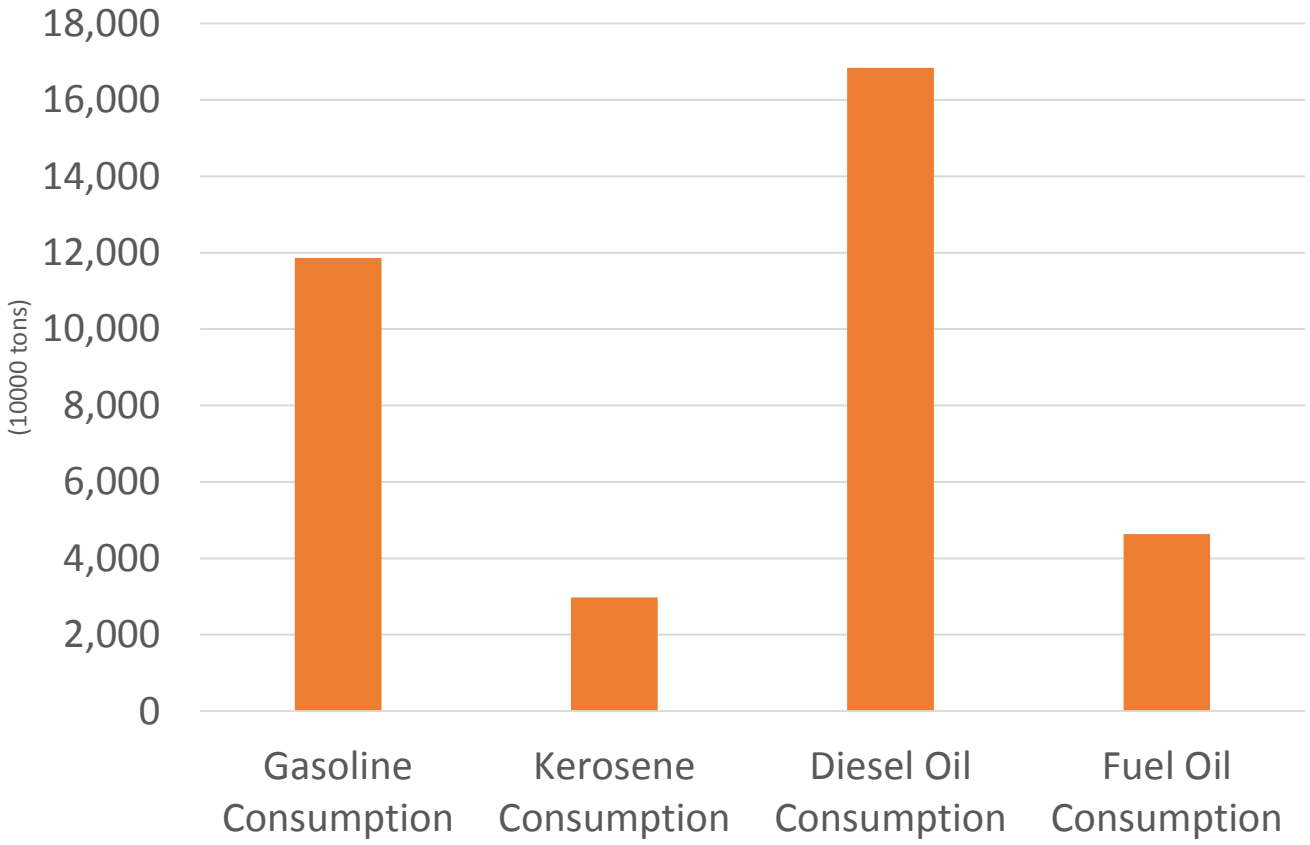
Raw materials: *Methyl or ethyl ester of fatty acids produced from non-edible vegetable oils, acid oil, used cooking oil or animal fat.*

Tons of oil equivalent to joules conversion formula

$$Energy(J) = Energy\ (TOE) \times 41868000000$$

CHINA

USDA, *Biofuels Annual Report*. Beijing_China_07-27-2020.



Bioethanol (Million Liters)	
Production (2019)	*10740*
Consumption (2019)	*10823*

Raw materials: Corn Kernals, Wheat Kernals, Cassava (dried chips), Rice (kernals), Sweet Sorghum and Cellulosic Biomass.

Biodiesel (Million Liters)	
Production (2019)	*939*
Consumption (2019)	*1,140*

Raw materials: *Used Cooking Oil.*

China Energy Portal
http://www.stats.gov.cn/english/Statisticaldata/AnnualData/

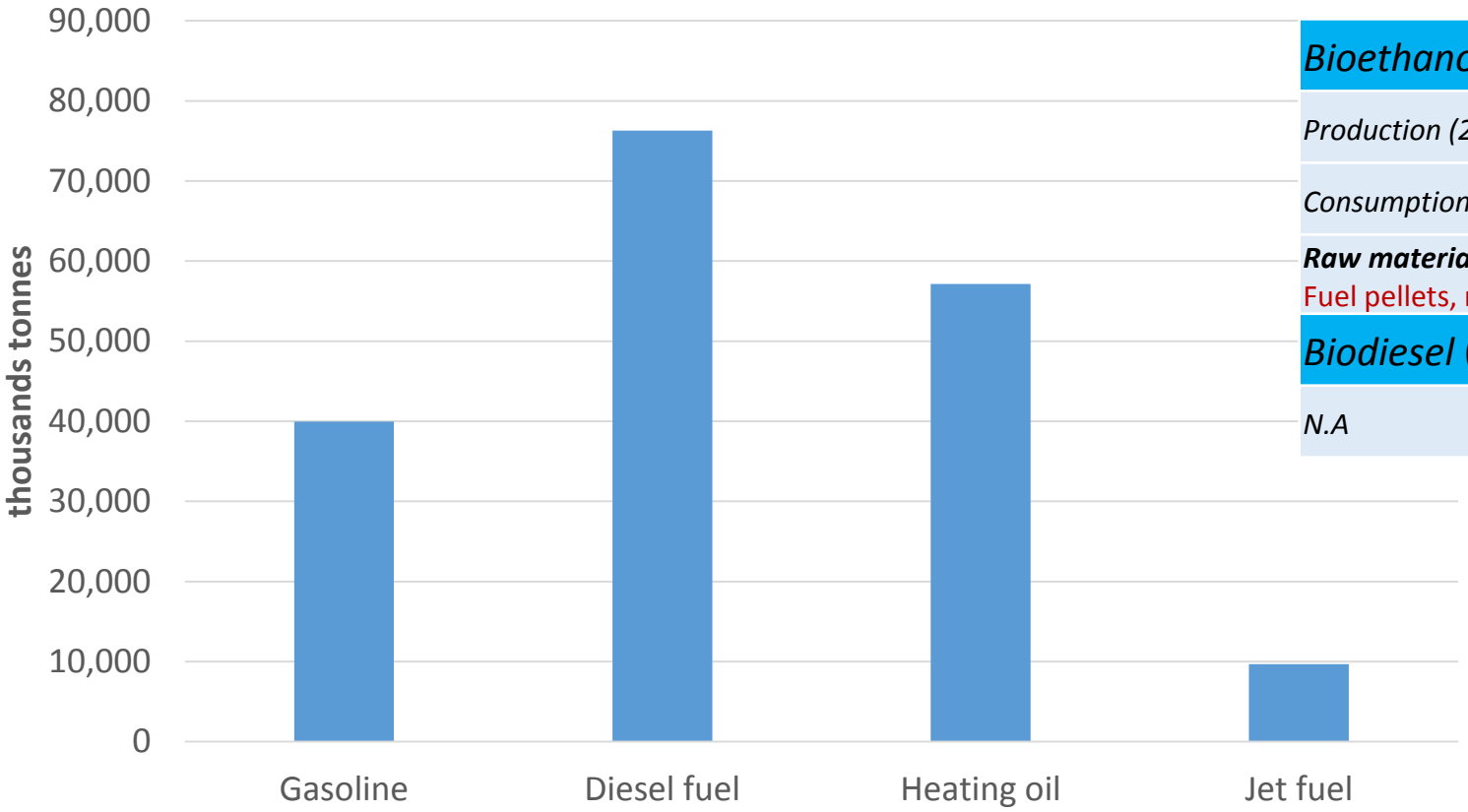
Tons of oil equivalent to joules conversion formula

$$Energy(J) = Energy\ (TOE) \times 41868000000$$

RUSSIA

Final energy production (2017)

USDA, *Annual_Moscow Russian Federation_6-9-2017.*



Bioethanol (Million Liters)	
Production (2019)	*935*
Consumption (2019)	*846*

Raw materials:
Fuel pellets, rapeseeds, and rapeseed oil

Biodiesel (Million Liters)	
N.A	-

Ministry of Energy of the Russian Federation
https://minenergo.gov.ru/en/activity/statistic

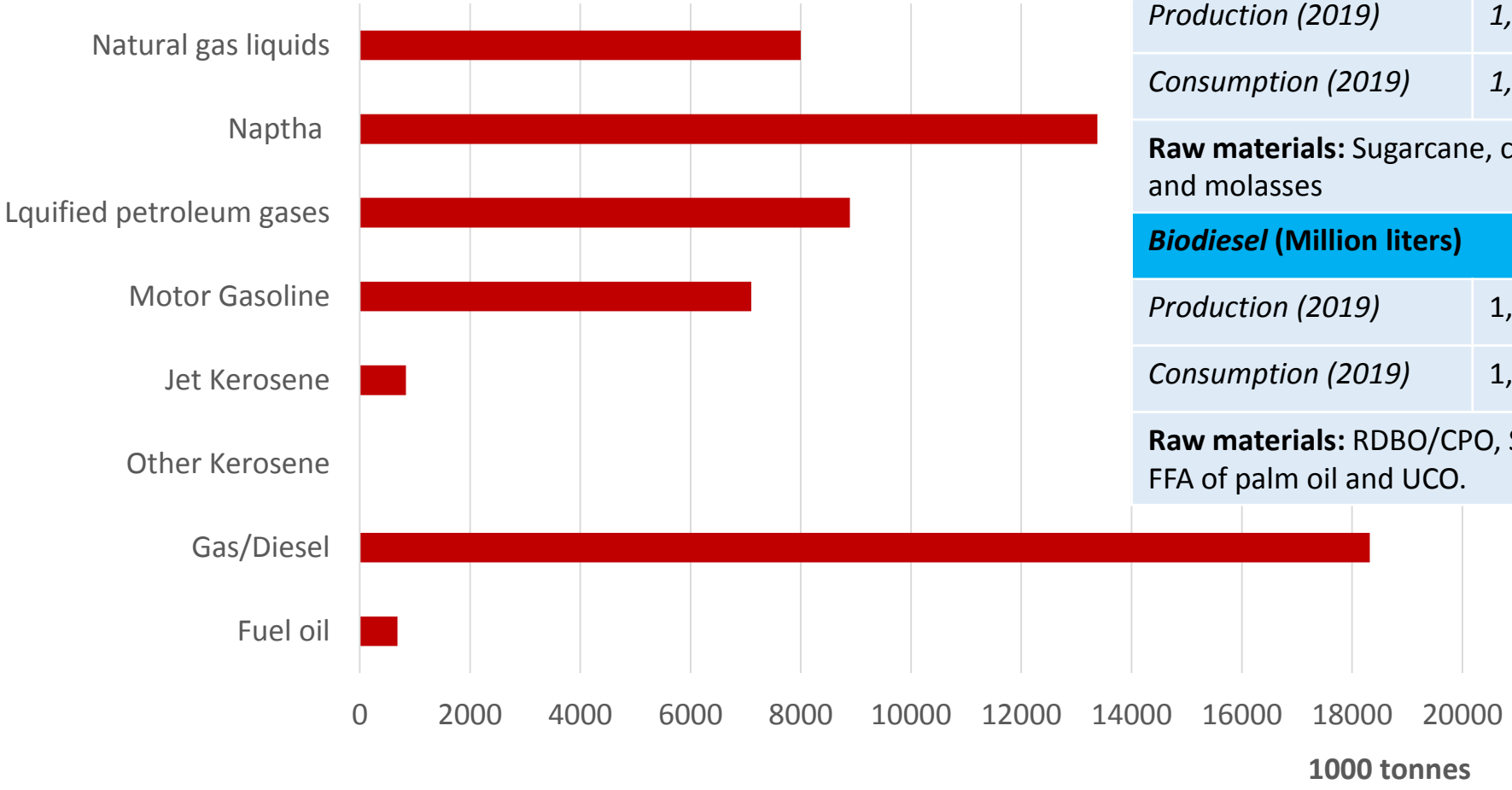
THAILAND

(2018)

USDA, *Biofuels Annual Report*. Bangkok_Thailand_12-19-2018.

Bioethanol **(Million liters)**	
Production (2019)	*1,485*
Consumption (2019)	*1,498*
Raw materials: Sugarcane, cassava and molasses	

Biodiesel **(Million liters)**	
Production (2019)	1,567
Consumption (2019)	1,568
Raw materials: RDBO/CPO, Stearin, FFA of palm oil and UCO.	



Tons of oil equivalent to joules conversion factor

1 ton of oil equivalent is equal to 41868000000 joules

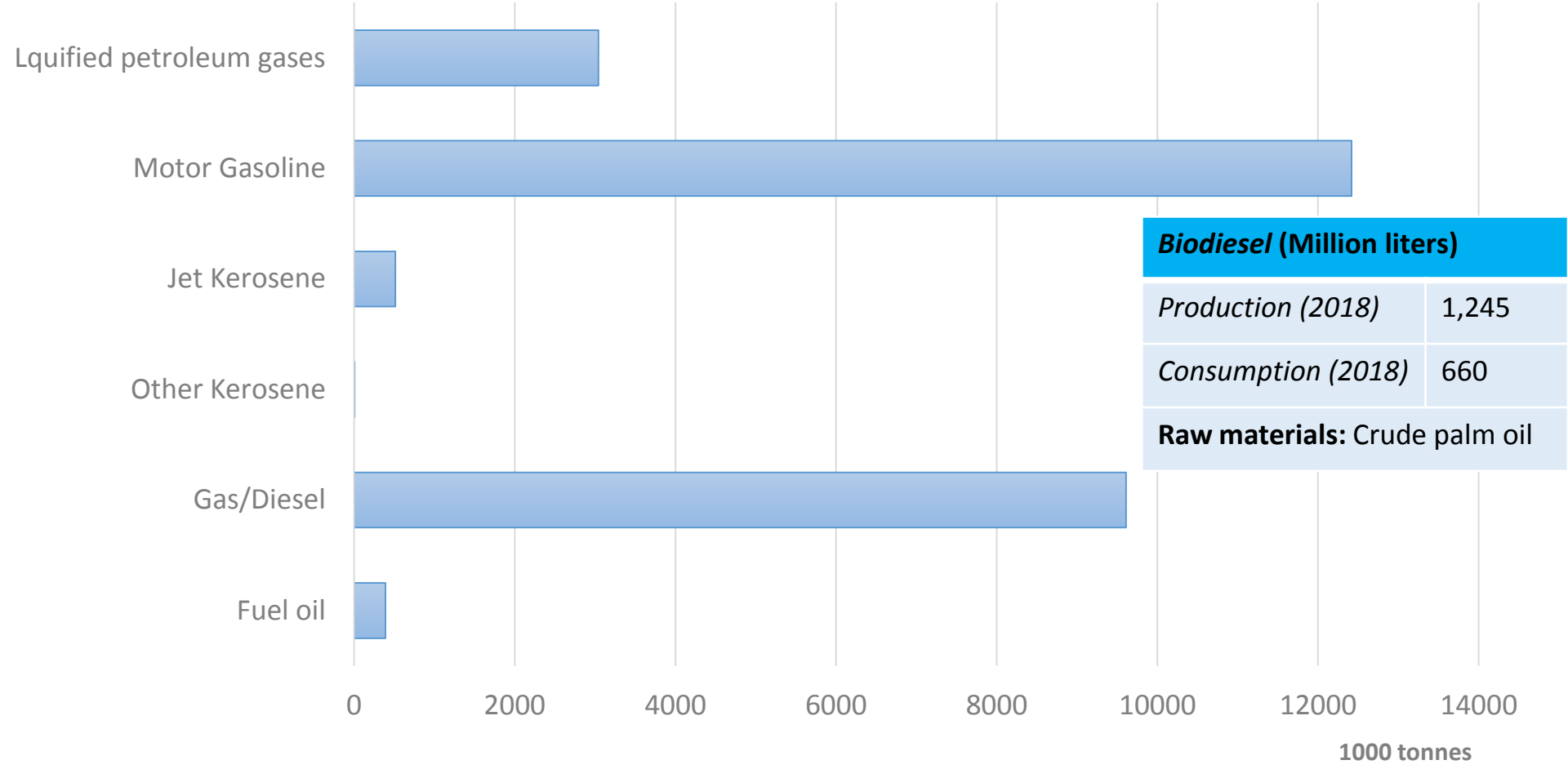
Thailand - The International Energy Agency

https://www.iea.org/countries/Thailand/

MALAYSIA

(2018)

USDA, *Biofuels Annual Report*.
Kuala Lumpur_Malaysia_10-28-2019



Biodiesel **(Million liters)**	
Production (2018)	1,245
Consumption (2018)	660
Raw materials: Crude palm oil	

Tons of oil equivalent to joules conversion factor

1 ton of oil equivalent is equal to 41868000000 joules

Malaysia - The International Energy Agency
https://www.iea.org/countries/Malaysia/

Challenges faced

1. Data quality and data validation *(Database step)*

2. Feedstock definition and technological pathways *(TRL)*

3. Data acquisition of crop yield per hectare *(by country)*

4. Evaluation standardization database *(year, efficiency, raw material, geographical location, etc.)*

5. Life Cycle Inventory database implementations

Final Comments | *take-home message*

- In general, the most important potential sources of biomass (in EJ terms) are energy crops, agricultural residues, forestry residues, and wastes (i.e. *used cooking oil for biodiesel production and municipal solid waste-MSW for bioethanol production*);
- Bioenergy has potential to be signinficant part of the energy matrix (biomass biofuels and biochemicals) for emerging economies focus on technological and social implications;
- Policy incentives mechanism assurance for biofuel production (*i.e.* Russia, Mexico, and South Africa does not show interest in biodiesel development); (i.e. Malaysia,

Extra Comments

Ethanol in hybrid vehicles with Lithium-ion battery

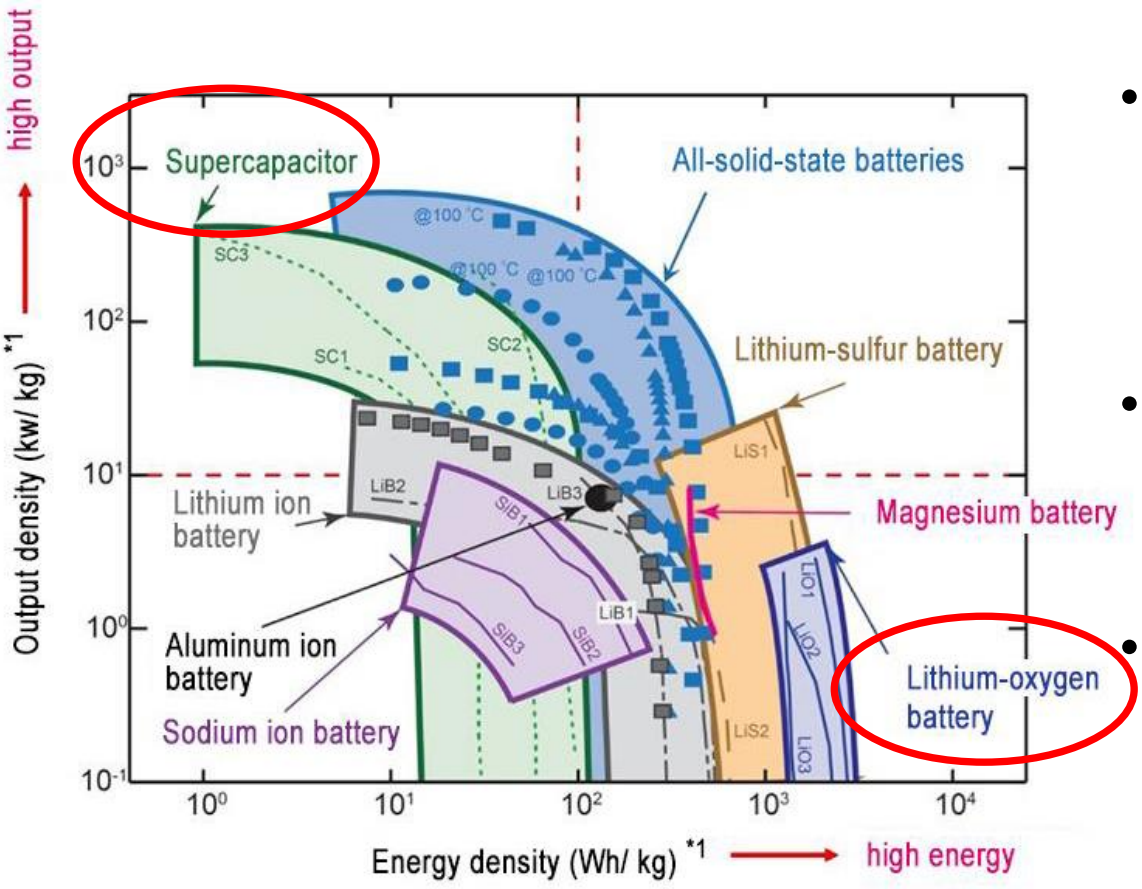
Model	Corolla GLi	Corolla Altis HV
Type	Flexible-fuel vehicle	Hybrid-flex vehicle
Fuel economy (*ethanol*)	8.0 km/l (18.8 mpg)	10.9 km/l (25.6 mpg)
Curb weight	1375 kg (3028 lb)	1440 kg (3172 lb)

Fuel economy in city with ethanol *95%*. Results from CONPET/INMETRO/Brazil.

- Hybrid vehicle increases the fuel economy in city driving by 36%.
  - Hybrid vehicle is only 5% heavier than flex-fuel vehicle.

https://www.toyota.com.br/modelos/corolla/
http://www.inmetro.gov.br/consumidor/pbe/veiculos_leves_2020.pdf

It is possible to increase battery performance?
Why Li-Air & Supercapacitors?
How much it will improve the car performance?



- Represent both ends for high energy and high output density
- Unanswered questions
- What are the main guidelines for the technology?

Zhang, X., Wang, X.-G., Xie, Z. & Zhou, Z. Recent progress in rechargeable alkali metal–air batteries. Green Energy Environ. 1, 4–17 (2016).

Thank you for your attention!

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