MAPPING FEEDSTOCK AVAILABILITY FOR THE PRODUCTION OF SUSTAINABLE AVIATION FUELS IN BRAZIL

BEEF TALLOW

RSB

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INTRODUCTION

RELEVANCE

AMBITOUS TARGETS

The International Civil Aviation Organization (ICAO) is pursuing the GHG reduction on international flights:

- Improve fleet fuel efficiency by 1.5% per year from 2009 to 2020
- Carbon Neutral Growth from 2020
- Reduction of GHG emissions by 50% in 2050, as compared to 2005

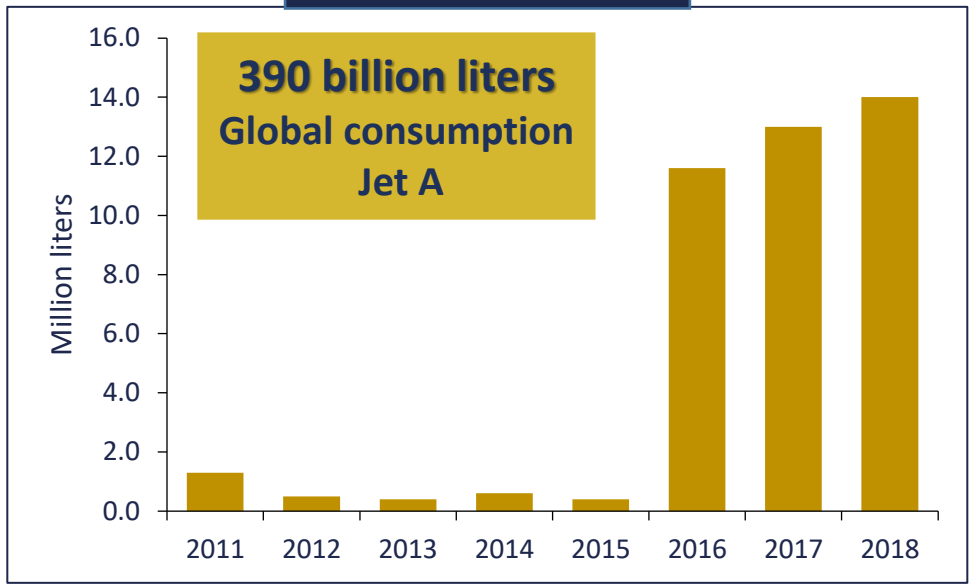
POSSIBLE PATHS

Improvements in the design and engine of aircrafts, or in the operations and infrastructure of aviation could help to achieve these targets. But they are limited.

SAF

Among the options, the substitution of fossil fuels by Sustainable Aviation Fuels (SAF) is considered the only one with the potential to achieve significant GHG reductions in the short-term.

SAF PRODUCTION



Source: ICAO (2020)

SAF must provide a reduction of, at least, 10% in GHG emissions when compared to fossil kerosene (on a life cycle basis), and must not have been obtained from high-carbon areas since 2008 (ICAO, 2019)

Thus, residual feedstocks are strategic options for significant GHG reductions, which will likely lead to low costs for SAF production.

GENERAL OBJECTIVES

IDENTIFY AND MAP

Identify and map alternative residual feedstocks for SAF production in Brazil, including CO-rich industrial off-gases, beef tallow, used cooking oil, forestry residues, and sugarcane residues (bagasse and straw).

POTENTIAL

Provide information about feedstock availability and potential production of SAF.

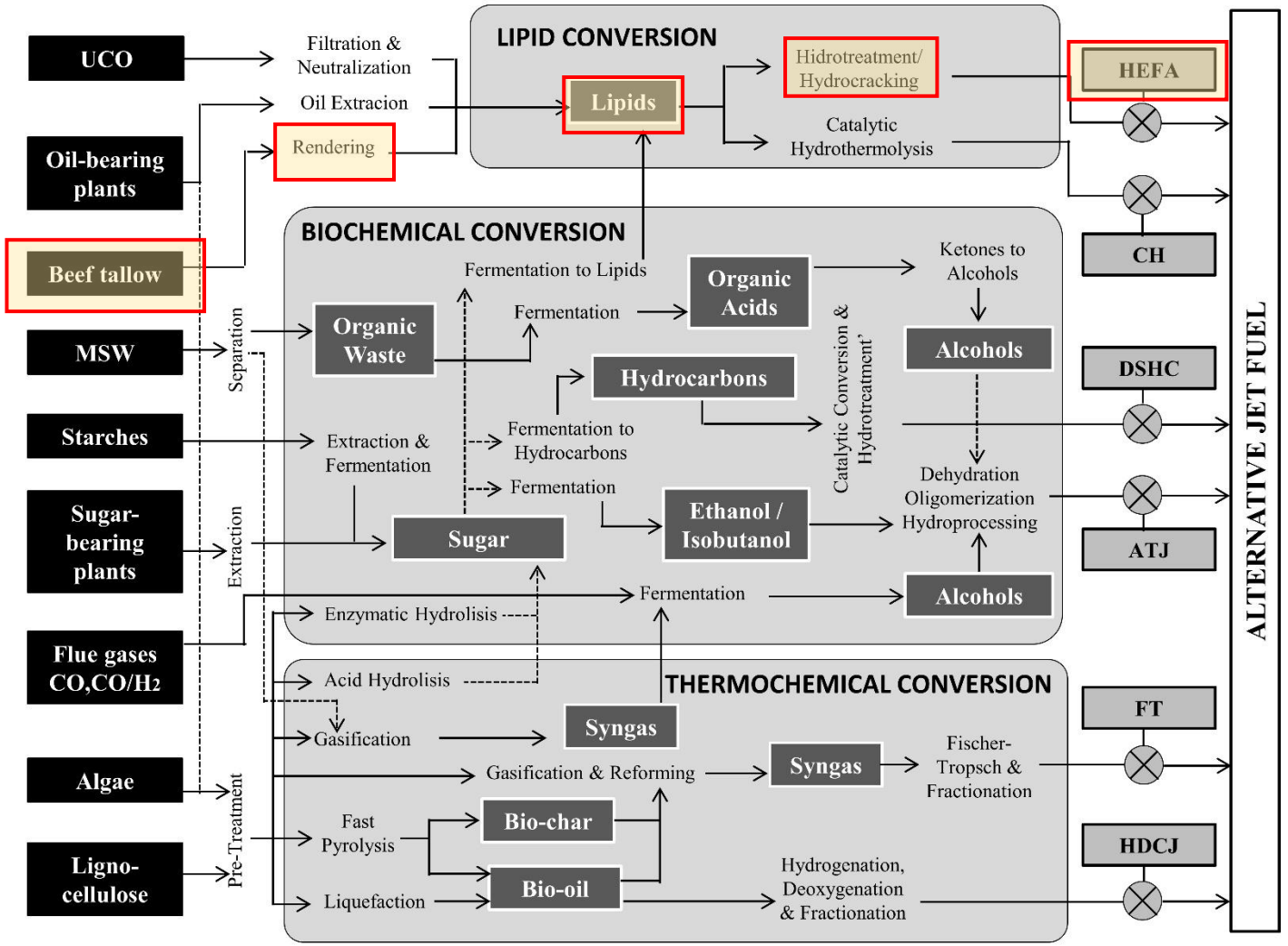
Pathway for SAF production:

Several pathways (feedstock + conversion technology) can be used to produce SAF. Some of them are currently approved or in the pipeline for approval by ASTM. An approved pathway means that the SAF produced is certified as a drop-in fuel and can be used with fossil kerosene within blending limits (v/v).

This case study focuses on beef tallow as a feedstock, using HEFA technology

Pathways for SAF production*

Source: Boeing (2013)



** ASTM recently approved the co-processing of vegetable oils, greases, and Fisher-Tropsch biocrude with fossil middle distillates in oil refineries (maximum blend 5% v/v). Co-processed fuels are not represented in this figure.*

OBJECTIVE OF THIS REPORT

General objective

To map the availability of beef tallow for SAF production, with high geographical detail, enabling the identification of investment opportunities.

Specific objectives:

- Identify the current production and availability of beef tallow in Brazil
- List the current applications of beef tallow
- Identify locations for feedstock collection and their production capacity
- Identify potential locations for processing industries (near HEFA plants)
- Identify the demand (airports)
- **Develop maps:**
  - Spatializing the availability of beef tallow
  - Matching the availability of beef tallow with potential processing locations
  - Matching potential processing locations with the consumption sites
  - Matching all the above with transport infrastructure (gas pipelines, harbors)

Source: https://www.healthbenefitstimes.com/beef-tallow-uses-and-benefits/

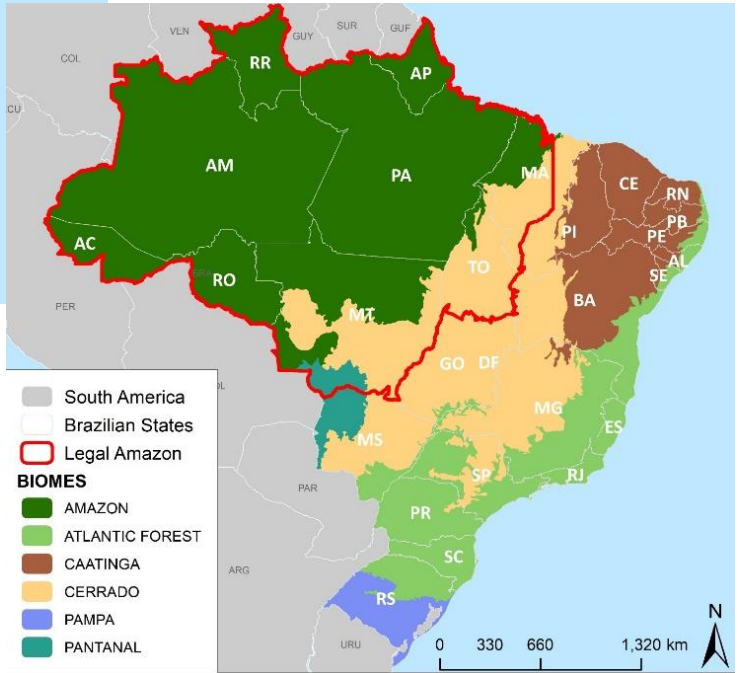
CONTEXT

GEOGRAPHY AND BOUNDARIES OF BRAZIL

The Federative Republic of **Brazil** is a country of continental dimensions, whose territory **covers around 8.5 million km²**.

Politically, **Brazil is divided into 27 federative units**, composed of 26 states and one federal district (where the national capital is located).

These federative units are subdivided into municipalities. The municipalities in the Northern region (in green) have much larger areas than in the Southeast, for example, due to historical and geographical reasons. This fact needs to be considered in order to understand the availability of feedstock, which is spatialized by availability in each municipality.

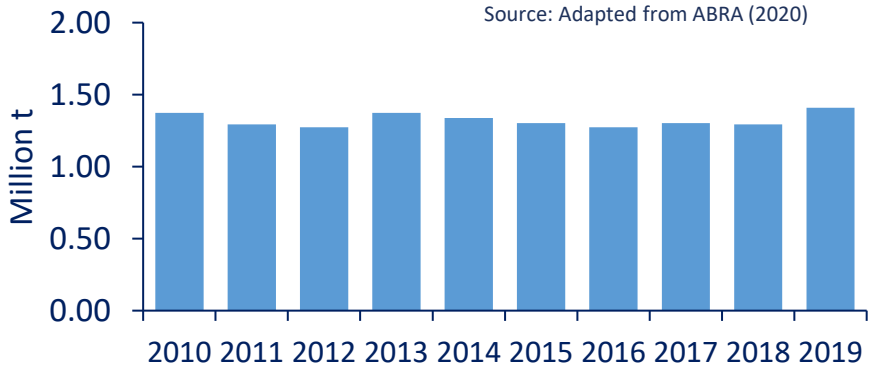


The second map displays the boundaries of the six Brazilian continental biomes: Amazon, Cerrado (or Brazilian savannah), Caatinga, Atlantic Forest, Pantanal and Pampa.

BEEF TALLOW

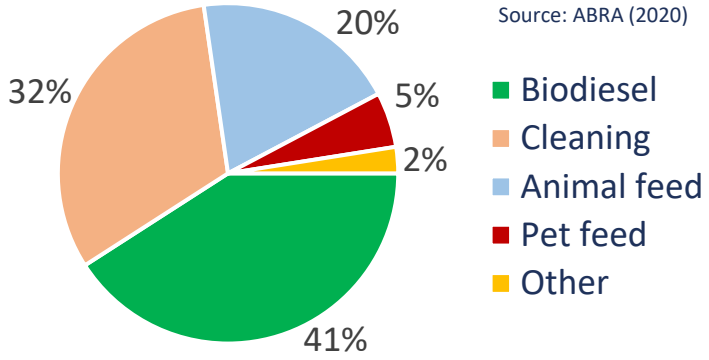
Beef tallow produced in Brazil

Source: Adapted from ABRA (2020)



Destination of tallow in Brazil (2019)

Source: ABRA (2020)



Beef tallow has a wide range of applications, being used in the formulation of feed and others. It can be used by the chemical, hygiene and cleaning industries, in the manufacture of varnishes, lubricants and others, such as in the pharmaceutical industry (glycerin). The main destination of Beef Tallow produced in Brazil is to produce Biodiesel (ABRA, 2020)

WHAT IS BEEF TALLOW?

Beef Tallow results from the secretion of the sebaceous glands, and is composed of fat, keratin and cellular debris, whose function is to protect the skin. Beef Tallow is a obtained simultaneously with the manufacture of Bone Meal and separated from the solid fraction through percolation and pressing processes. The raw material for Beef Tallow is obtained from establishments that are supervised by competent authorities. The Beef Tallow production process follows the rules of the Ministry of Agriculture, Livestock and Supply of Brazil (MAPA) (ABRA, 2020).

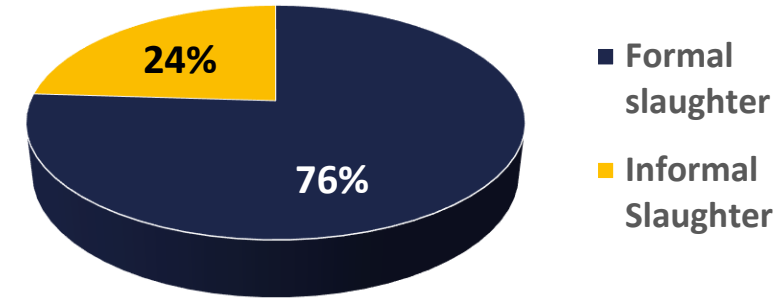
WHAT ARE THE MAIN ADVANTAGES OF BEEF TALLOW?

- **Costs:** tallow is expected to have a low cost, when compared to other raw materials
- **Safety:** safe and stable product at room temperature
- **Biofuel:** it is an alternative to the use of vegetable sources in the production of biodiesel and biojet.

In 2019, Beef tallow was the second most used raw material in the production of biodiesel in Brazil, representing around 12% of Brazilian Biodiesel (ANP, 2020). In 2019, the beef tallow provided revenue of around **1.4 billion BRL** in the internal market (ABIEC, 2020)

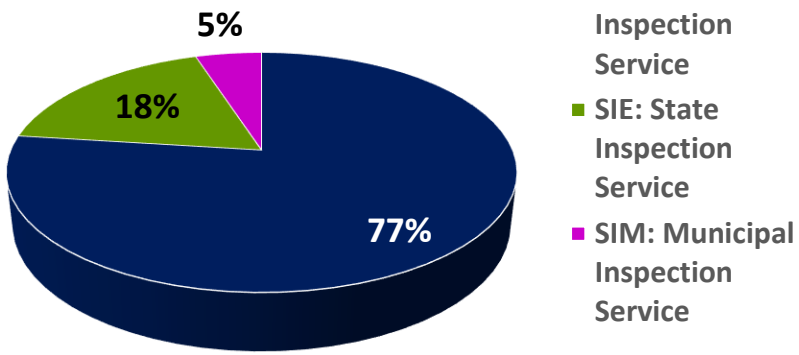
SUPPLY CHAIN: BEEF TALLOW

Formal and informal slaughter in Brazil (% of the market, on cattle head basis)



Source: ABIEC (2020)

Beef slaughter certification in Brazil, 2018 (on cattle heads basis)



Source: IBGE (2018)

FORMAL AND INFORMAL SLAUGHTER

In Brazil, all cattle intended to be sold to the consumer market is required to be slaughtered in slaughterhouses with sanitary inspections for health and taxation purposes. This is the formal market. However, a significant part of the market (10 million heads, which represents 24% of the total slaughter) is estimated to have been processed in the “informal” market in 2019.

FORMAL SLAUGHTER SEALS IN BRAZIL: SIF, SIE, and SIM

The formal market is divided into three seals. The SIF (Federal Inspection Service), SIE (State Inspection Service) and SIM (Municipal Inspection Service) seals are inspection seals for products of animal origin, whether they are edible or not, at the federal, state and municipal levels of government. The commercialization of these items is subject to inspection and these seals supervise quality standards and contamination control. They are essential parameters and have a safety role.

ADVANTAGES OF SELECTING SIF SEALS FOR SAF PRODUCTION

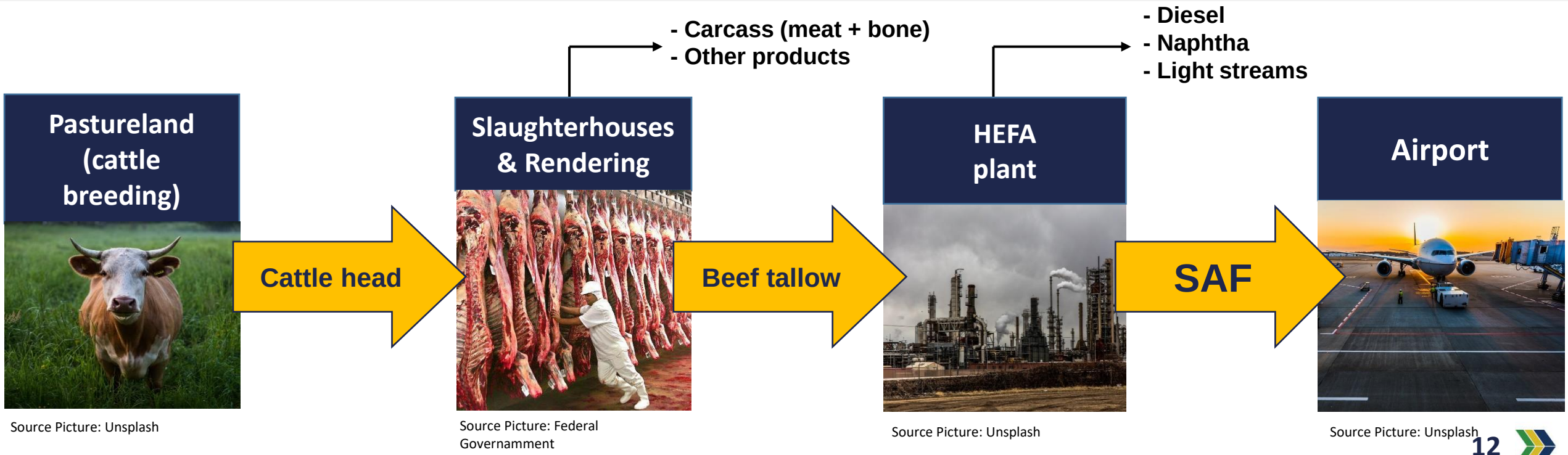
SIF is the inspection category that is suited to meet international standards and provides greater supply chain traceability. According to official statistics, SIF slaughter represents the majority of formal slaughter in Brazil. For the year 2018 (reference year of this report), 23.5 million animals were slaughtered in SIF slaughterhouses, representing around 77% of total bovine formal slaughter.

SUPPLY CHAIN FOR HEFA PATHWAY FROM BEEF TALLOW

Beef tallow is obtained during the rendering of wastes generated from carcass cleaning, such as bone, guts, and greases. In Brazil, rendering plant is commonly attached to the slaughterhouses.

After that, beef tallow is transported to a HEFA plant, which is currently the best-known process for SAF production and has been tested in large-scale. In the process, the oleaginous feedstock undergoes hydrotreatment with hydrogen in the presence of a catalyst. Unsaturated carbon-bonds are saturated, and oxygen is removed. Subsequently, the hydrocarbon chains are hydrocracked in different ranges, isomerized and, finally, fractioned, producing SAF and other products, such as diesel, naphtha, and propane.

Finally, the SAF would be distributed to consumption sites, considering that the blending of SAF and fossil kerosene (Jet A) would occur at the airport.



Source Picture: Unsplash

Source Picture: Federal Governamment

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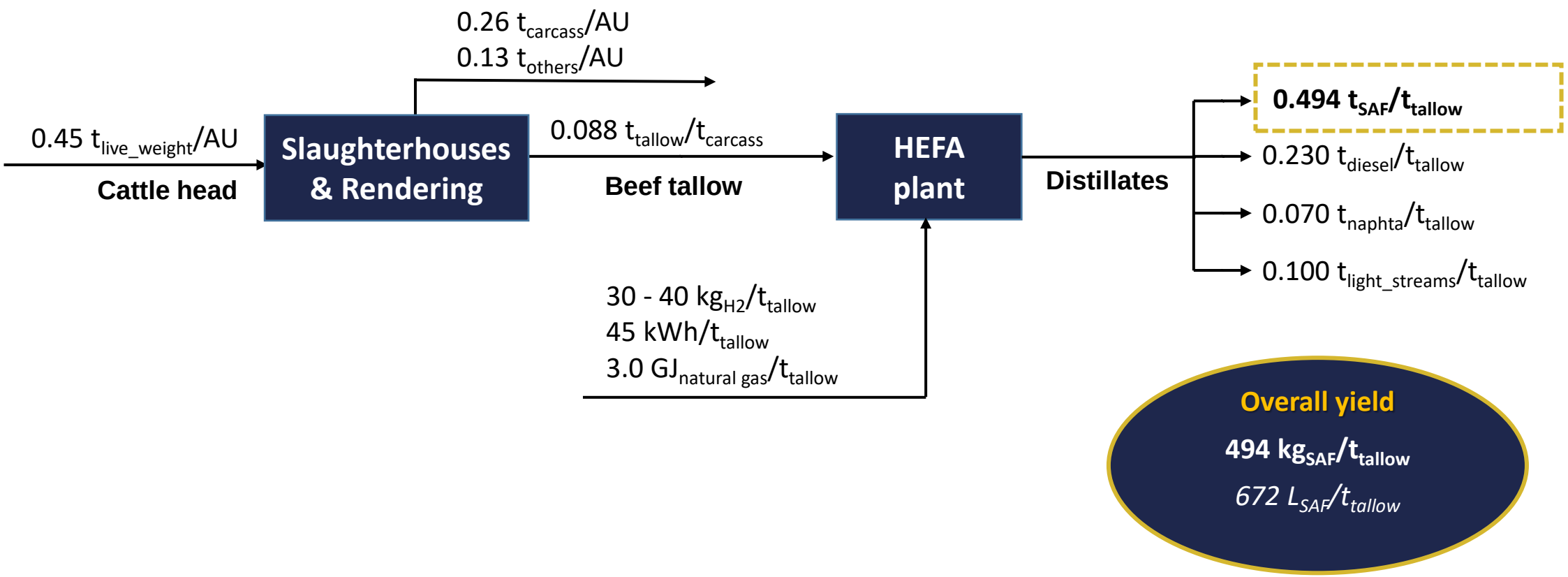
SUPPLY CHAIN: General yields and main inputs



Sources: based on Garcilasso (2014), Pearlson et al., (2013).
Note: 1 AU
*Animal weight is variable, depending on several variables including genetics, nutrition, climate, etc. As a convention, sectorial statistics normalize animals' statistics using Animal Unit as reference. One AU is equivalent to 450 kg.

FEEDSTOCK AVAILABILITY

GENERAL ASSUMPTIONS

The estimates of potential availability of beef tallow were calculated based on:

- Slaughters with federal inspection (SIF) from the quarterly slaughter survey (Source: IBGE, 2018);
- Generation rate: 0,088 t_{beef_tallow} / $t_{carcass\_slaughtered}$ (Source: Garcilasso, 2014);

INPUT DATA

Location and capacity of national SIF slaughterhouses

Source: Lapig (2017); MAPA – Brazil Agriculture Department (2019)

Slaughter data per Brazilian State

Source: IBGE (2018)

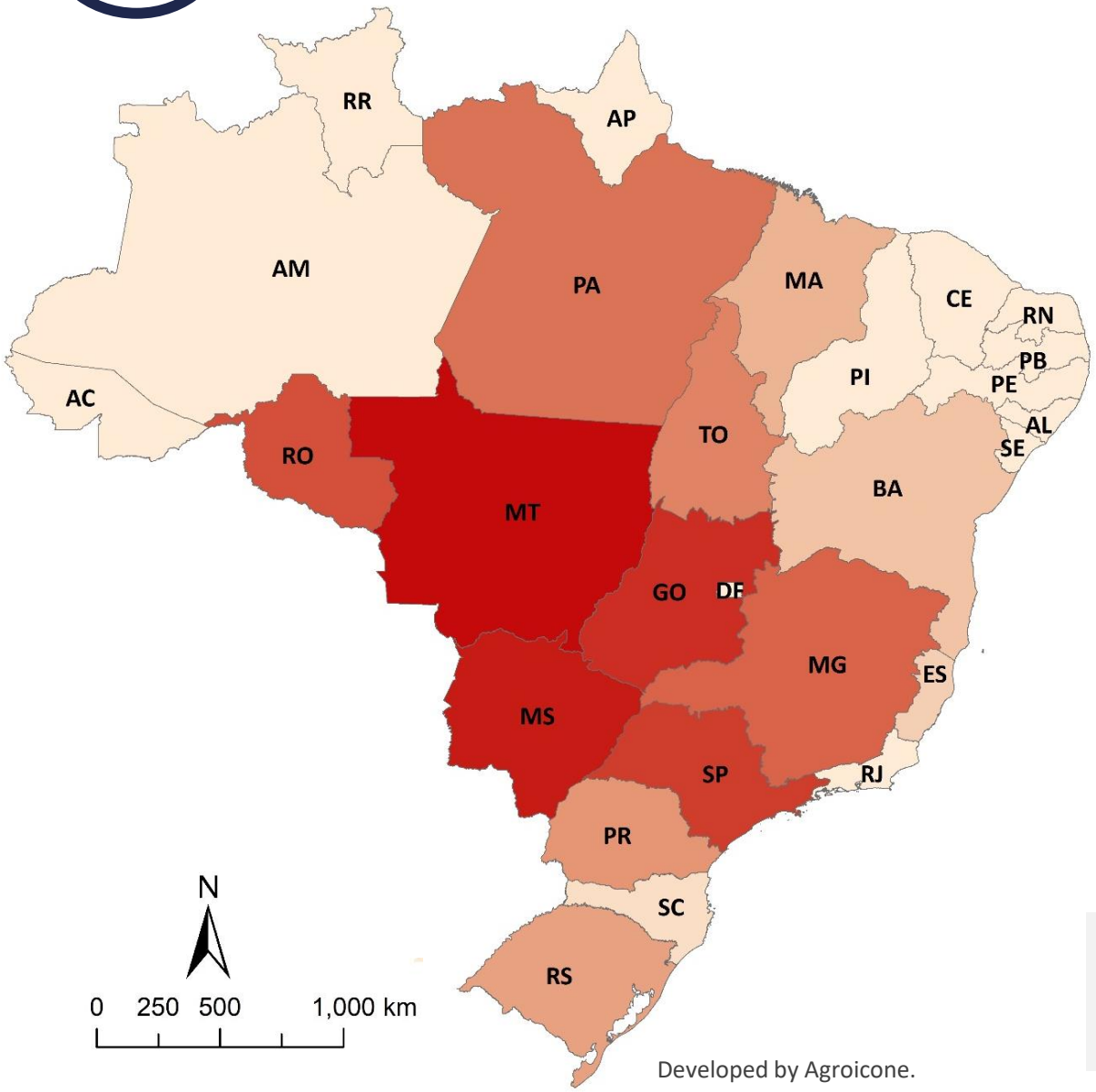
Jobs related to cattle slaughters in municipalities with SIF slaughterhouses

Source: Brazil (2020)

SCOPE OF THIS SECTION

The values of carcass weight slaughtered in each State were converted to tallow. Subsequently, this data was allocated to municipalities that had at least one slaughterhouse with federal inspection, using as a criterion the number of jobs related to cattle slaughter for each municipality. This data showed a correlation rate of 98%. See additional details in **ANNEX 1.**

BEEF TALLOW AVAILABILITY PER STATE IN BRAZIL



Developed by Agroicone.

State	Heads slaughtered (10^3 cattle head)	Total Weight (10^3 t _carcass)	Beef Tallow (10^3 t)
MT	4,844	1,314	115.7
MS	2,931	746	65.7
GO	2,631	705	62.0
SP	2,495	683	60.1
RO	2,325	573	50.5
MG	2,155	539	47.5
PA	2,007	532	46.8
TO	965	240	21.1
PR	895	230	20.2
RS	895	205	18.1
MA	187	101	8.9
BA	328	88	7.7
ES	167	47	4.1
SC	113	24	2.1
Total	22,939	6,027	530.4

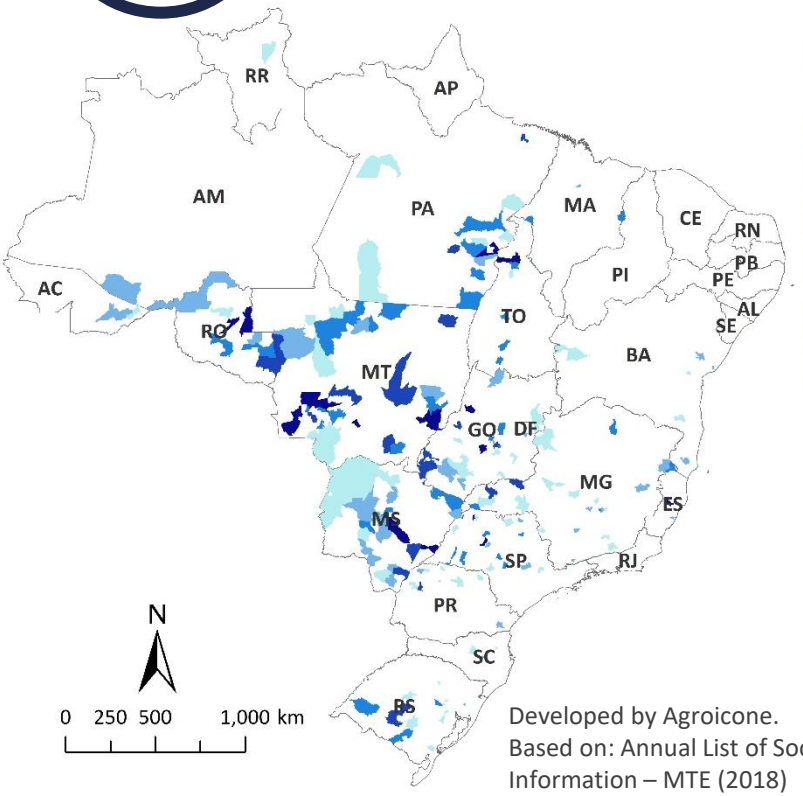
Source: Quarterly Slaughter Survey – IBGE (2018)

Note: animal weight depends on several factors. Since the quantity of tallow tends to depend on cattle weight, it is preferable to use the observed weight instead of a normalized (UA) weight for the purposes of this study.

VALIDATION

According to the Annual Livestock Profile Report in Brazil (ABIEC), the slaughters with Federal Inspection in 2017 were responsible by roughly **23 million of slaughtered cattle heads.**

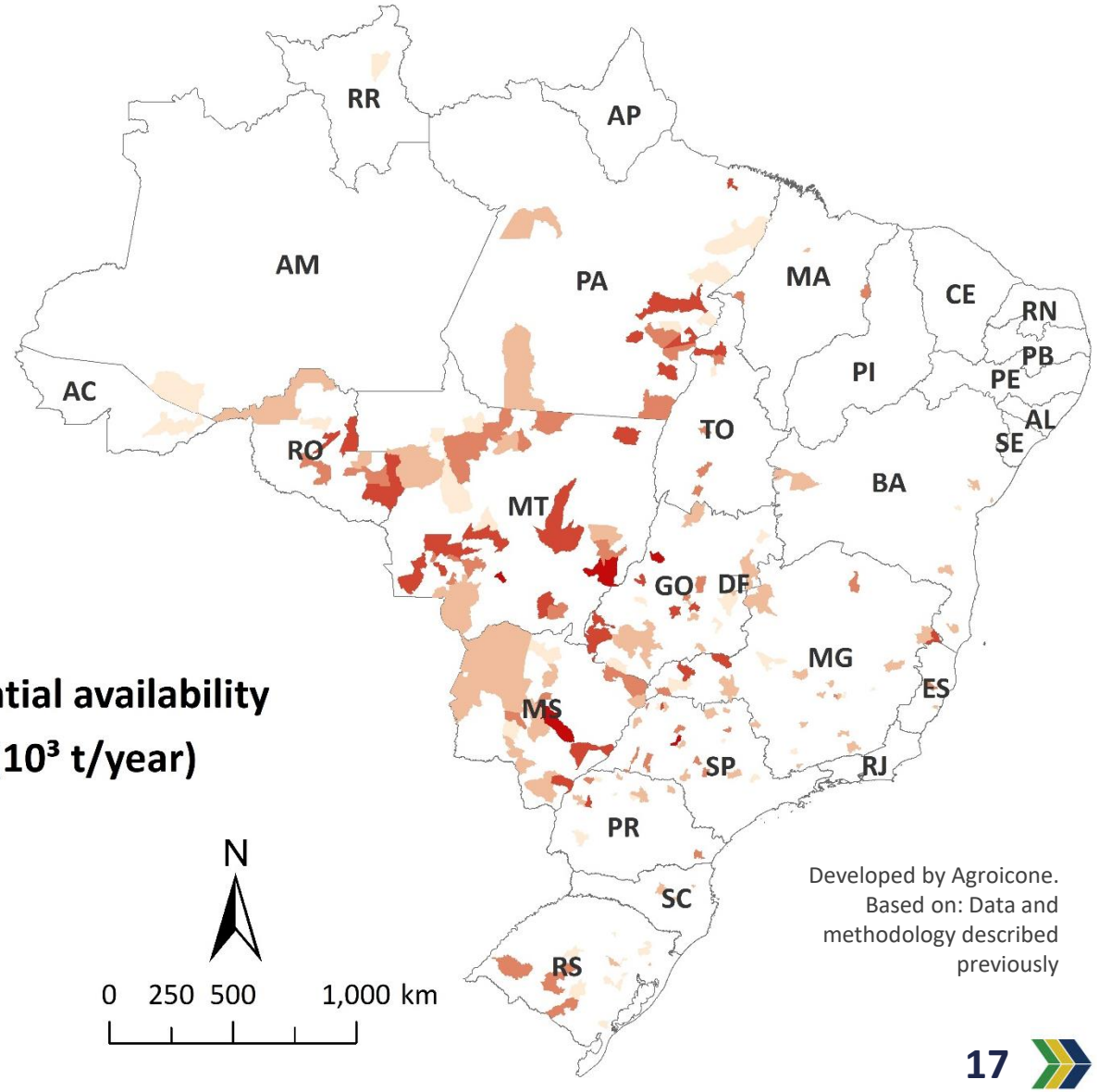
BEEF TALLOW POTENTIAL AVAILABILITY PER MUNICIPALITY



Jobs related to cattle slaughter per municipality (2018)

- 1 - 250
- 251 - 500
- 501 - 1000
- 1001 - 1500
- more than 1501

Developed by Agroicone.
Based on: Annual List of Social Information – MTE (2018)



Beef tallow potential availability per municipality (10^3 t/year)

- up to 0.5
- 0.5 to 2.5
- 2.5 to 5.0
- 5.0 to 10.0
- more than 10.0

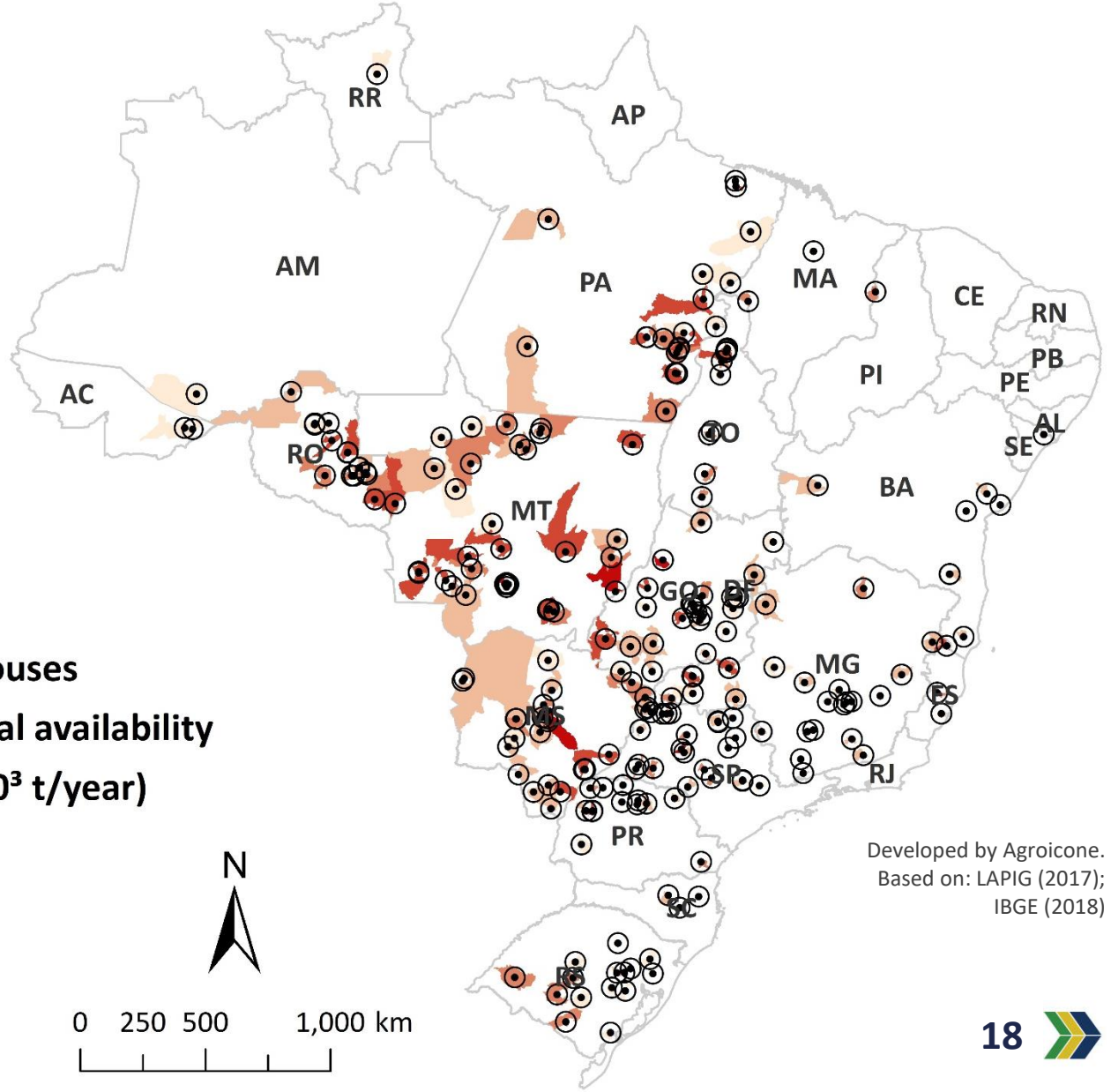
Developed by Agroicone.
Based on: Data and methodology described previously

The number of jobs related to cattle slaughter was used to allocate the State's beef tallow production proportionally into the municipalities where the slaughterhouses are installed.

BEEF TALLOW POTENTIAL AVAILABILITY PER MUNICIPALITY

The total potential availability of beef tallow with SIF inspection in Brazil is more than

530 10^3 t



Developed by Agroicone.
Based on: LAPIG (2017); IBGE (2018)

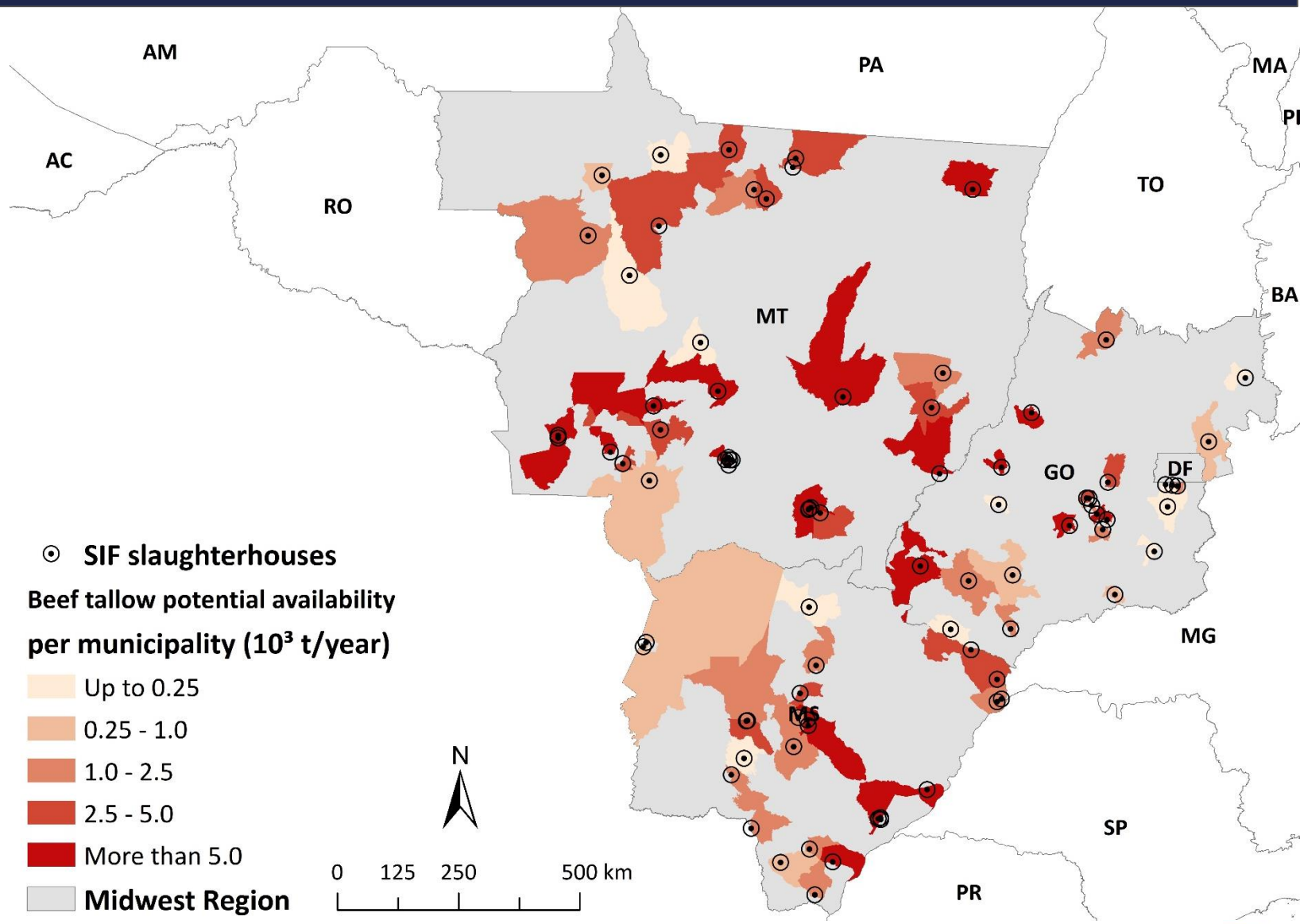
BEEF TALLOW AVAILABILITY IN THE MIDWEST REGION OF BRAZIL

The Midwest region concentrates more than

240 10^3 t

of beef tallow potential

TOP 5 MUNICIPALITIES		
Municipality - State	**Jobs in the sector**	**Beef Tallow (10^3 t)**
VÁRZEA GRANDE - MT	3173	16.5
CAMPO GRANDE - MS	3036	15.2
MOZARLÂNDIA - GO	2009	10.7
BARRA DO GARÇAS - MT	1930	10.0
TANGARÁ DA SERRA - MT	1867	9.6

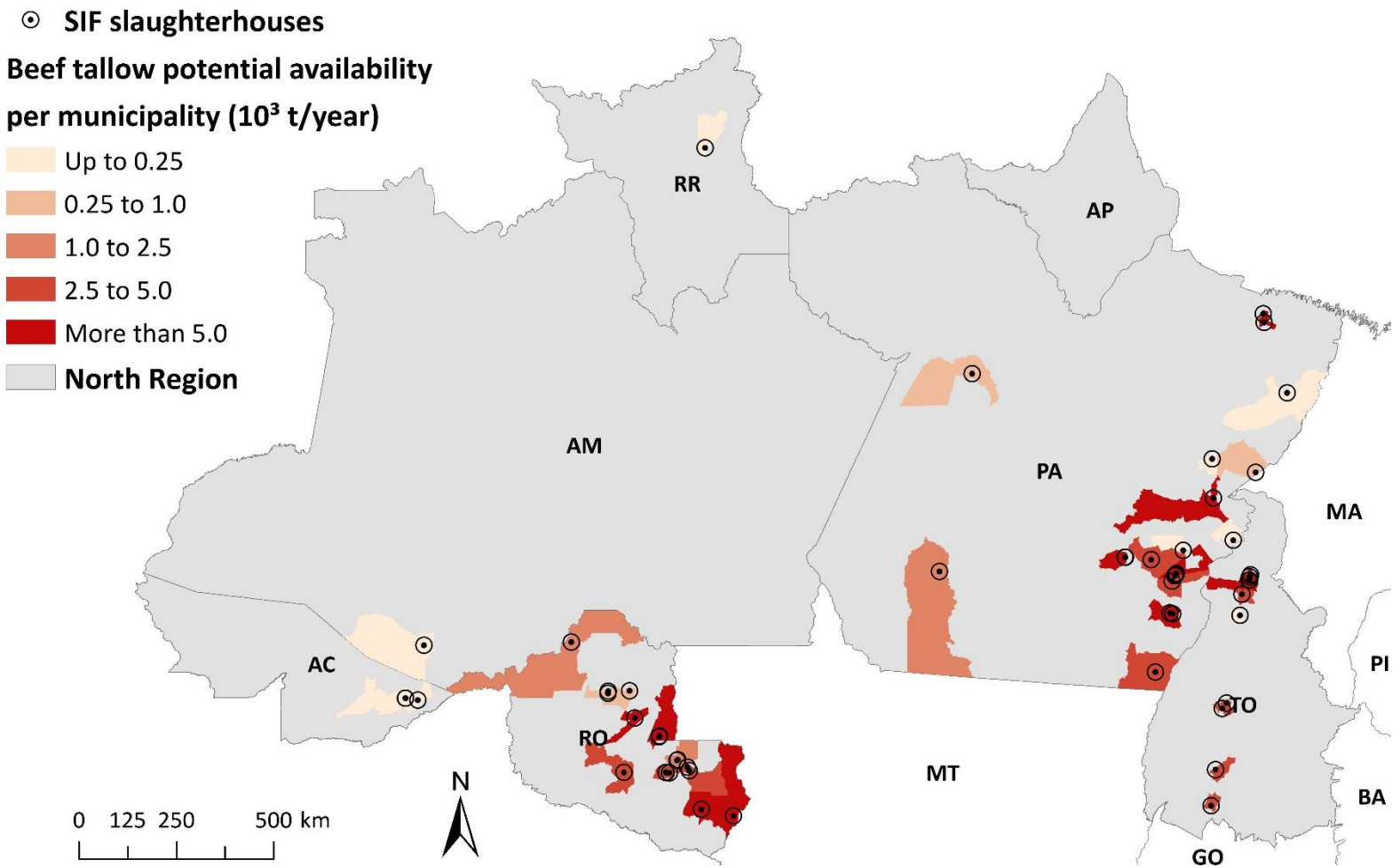


Developed by Agroicone.
Based on: LAPIG (2017); IBGE (2018)

BEEF TALLOW AVAILABILITY IN THE NORTH REGION OF BRAZIL

Potential availability of beef tallow in the North region is of more than

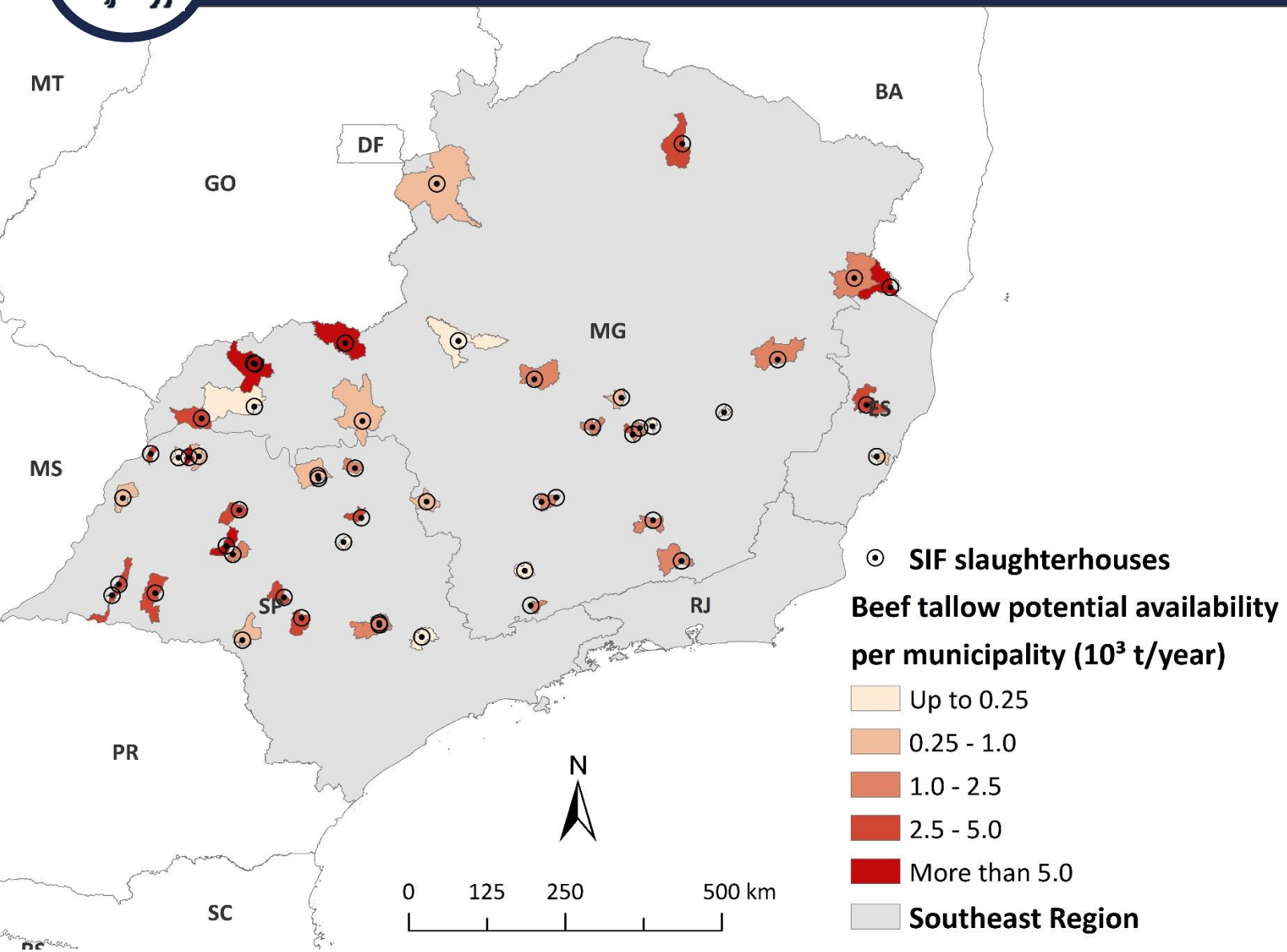
115 10^3 t



TOP 5 MUNICIPALITIES		
Municipality - State	Jobs in the sector	Beef Tallow (10^3 t)
JARU-RO	1937	9.9
XINGUARA-PA	1584	9.5
ARAGUAÍNA-TO	1815	8.9
JI-PARANÁ-RO	1717	8.8
VILHENA-RO	1447	7.4

Developed by Agroicone.
Based on: LAPIG (2017); IBGE (2018)

BEEF TALLOW AVAILABILITY IN THE SOUTHEAST REGION OF BRAZIL



In the Southeast region the potential availability f beef tallow is roughly

110 10^3 t

TOP 5 MUNICIPALITIES		
Municipality - State	Jobs in the sector	Beef Tallow (10^3 t)
PROMISSÃO-SP	2297	11.3
ESTRELA D'OESTE-SP	1761	8.7
ARAGUARI-MG	1166	6.4
ITUIUTABA-MG	1123	6.1
NANUQUE-MG	991	5.4

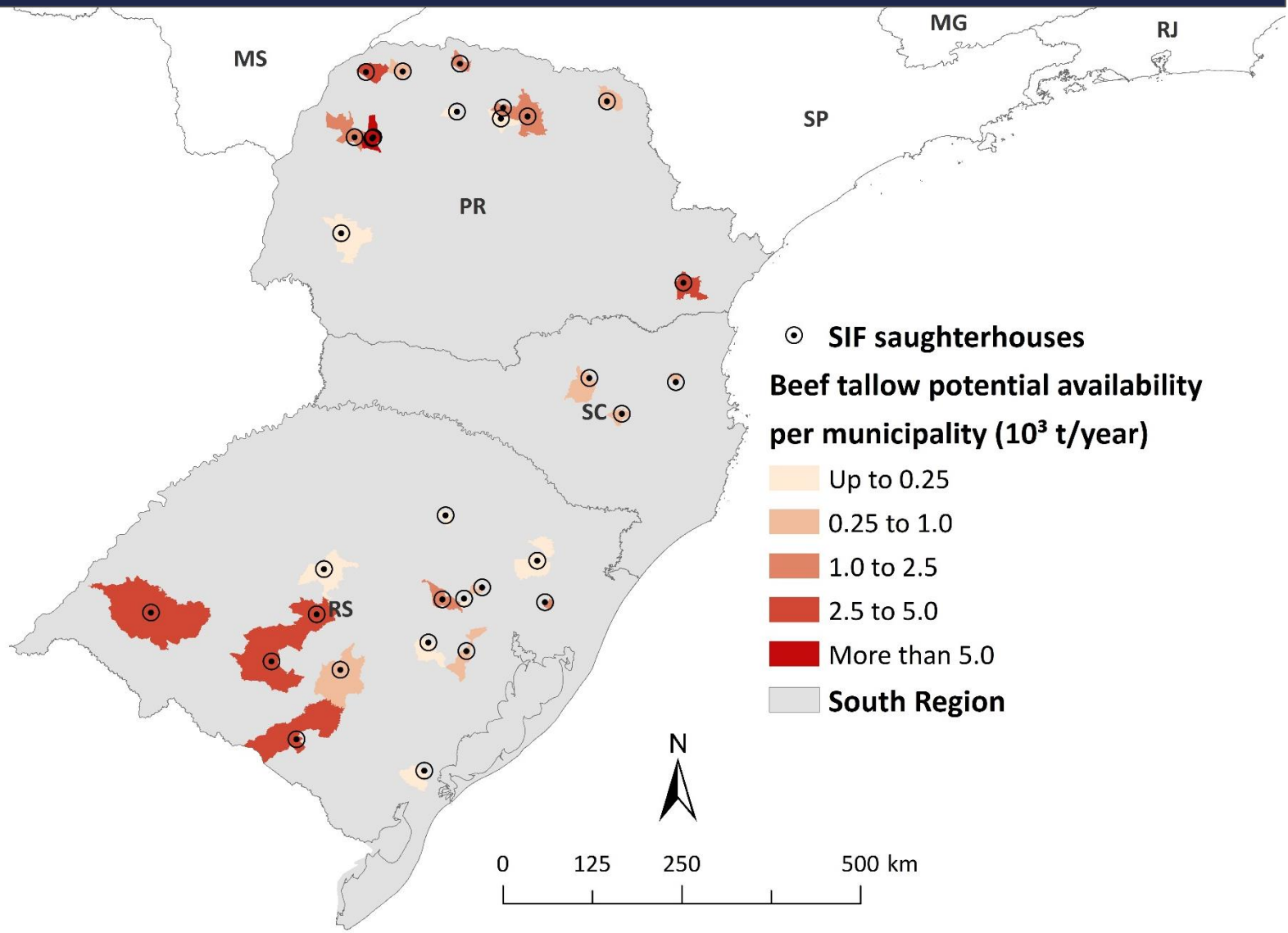
Developed by Agroicone.
Based on: LAPIG (2017); IBGE (2018)

BEEF TALLOW AVAILABILITY IN THE SOUTH REGION OF BRAZIL

In the South region, the potential availability f beef tallow is roughly

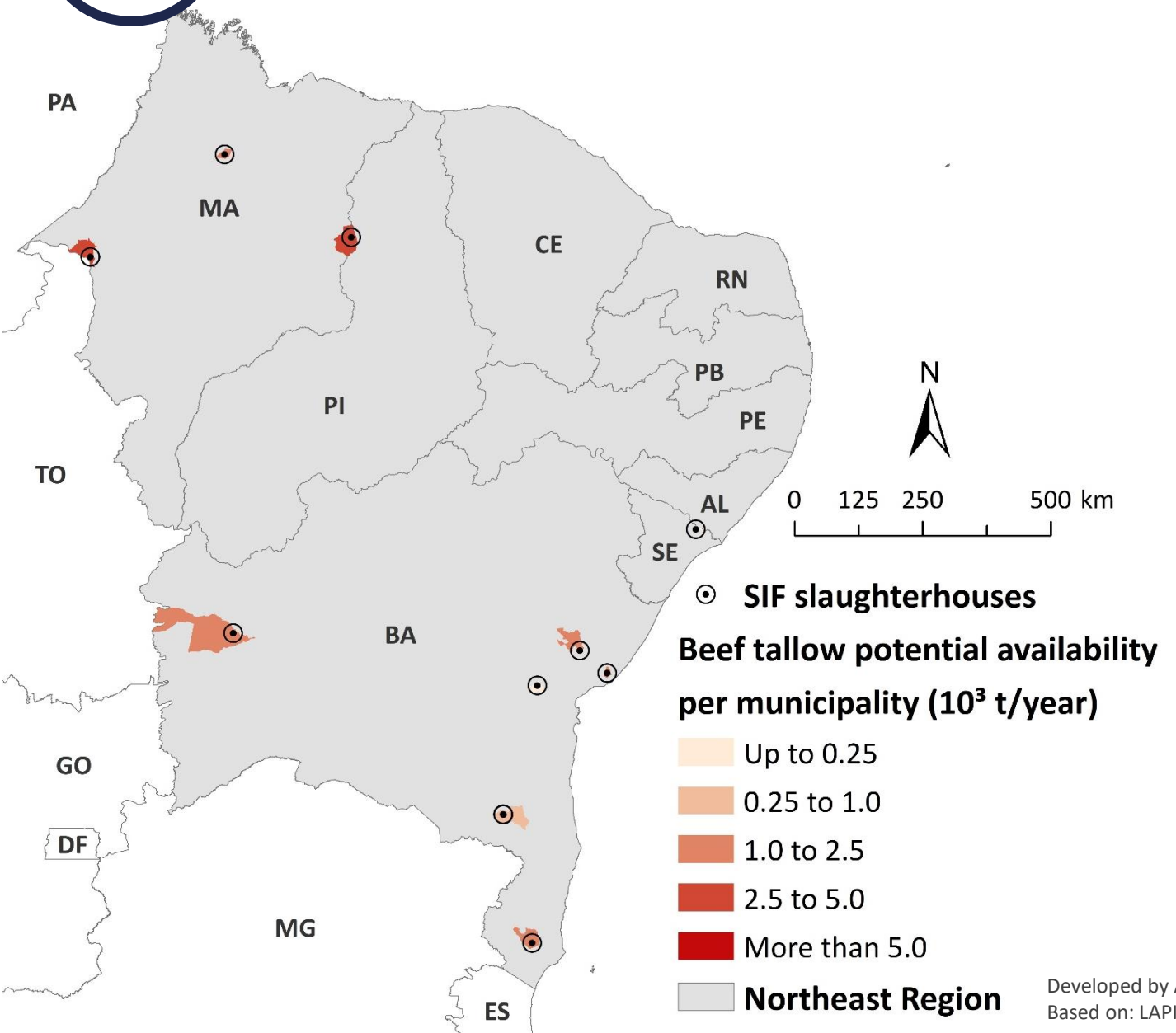
110 10^3 t

TOP 5 MUNICIPALITIES		
Municipality - State	**Jobs in the sector**	**Beef Tallow (10^3 t)**
CRUZEIRO DO OESTE-PR	1137	8.4
SANTA MARIA-RS	1138	4.0
SÃO GABRIEL-RS	1019	3.6
BAGÉ-RS	940	3.3
SÃO JOSÉ DOS PINHAIS-PR	404	3.0



Developed by Agroicone.
Based on: LAPIG (2017); IBGE (2018)

BEEF TALLOW AVAILABILITY IN THE NORTHEAST REGION OF BRAZIL



The potential availability of beef tallow in the Northeast region is more than

16 10^3 t

TOP 5 MUNICIPALITIES		
Municipality - State	Jobs in the sector	Beef Tallow (10^3 t)
TIMON-MA	542	3.3
IMPERATRIZ-MA	523	3.1
IGARAPÉ DO MEIO-MA	412	2.5
TEIXEIRA DE FREITAS-BA	345	2.2
SIMÕES FILHO-BA	311	2.0

Developed by Agroicone.
Based on: LAPIG (2017); IBGE (2018)

MATCHING BEEF TALLOW AVAILABILITY WITH PROCESSING SITES AND DEMAND

GENERAL ASSUMPTIONS

Regarding the SAF production from beef tallow, the spatially explicit data of feedstock availability was combined with possible processing sites and consumers according to the following assumptions:

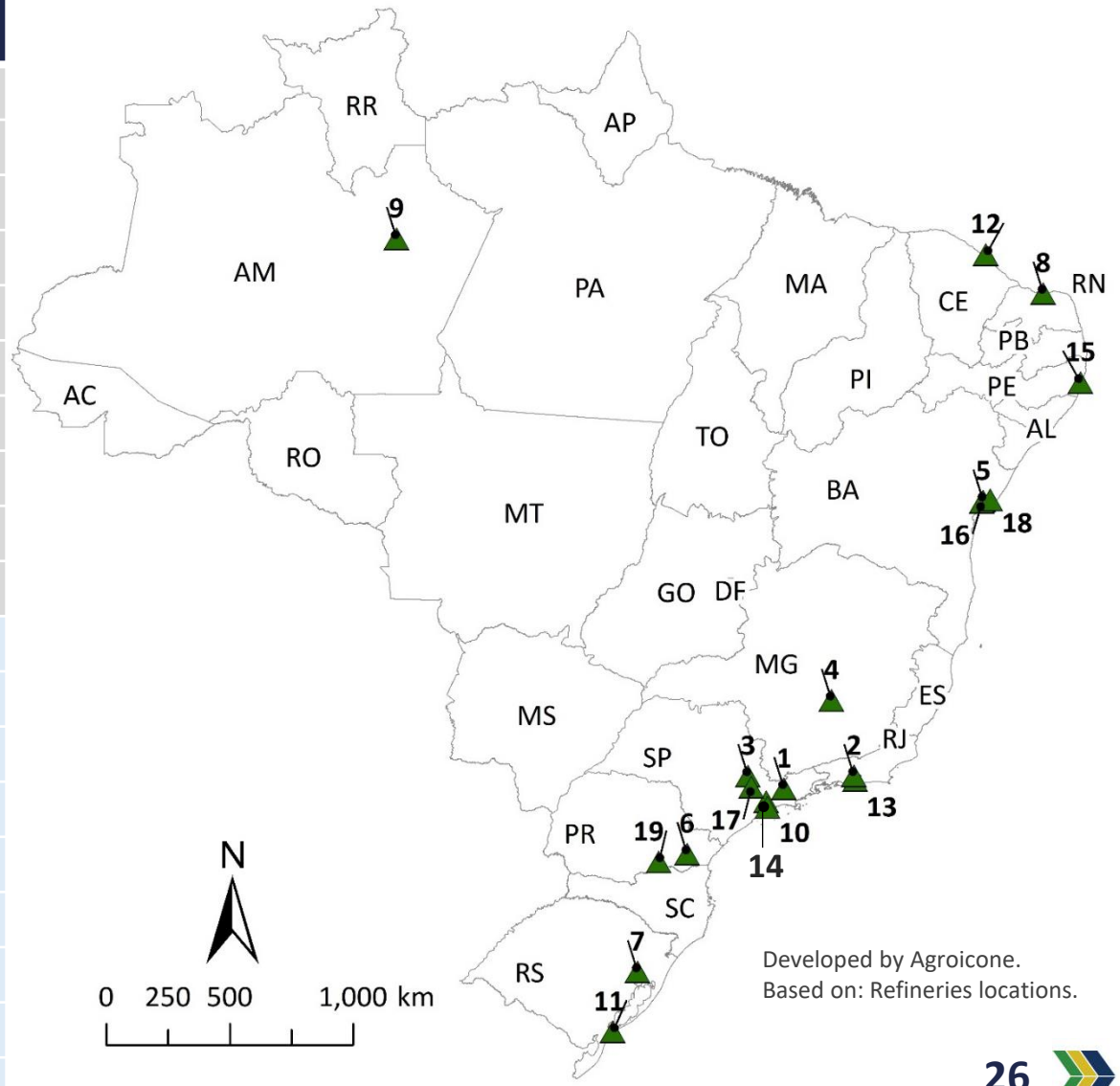
- Beef tallow must be collected at slaughterhouses since the rendering plants are typically integrated into the slaughterhouses in Brazil.
- HEFA plant, where beef tallow is converted into SAF, should be close to an oil refinery due to hydrogen demand for hydrotreating process and process integration possibilities.
- Alternatively, HEFA plants may be located near natural gas pipelines for possible hydrogen production through Steam Methane Reform.
- Before to supply an aircraft, SAF must be blended with Jet A.
- Considering that the targets on GHG reduction are related to international flights, only the international airports' supply was considered here.

OIL REFINERIES

According to ANP (2019), the map present the of the Brazilian oil refineries.

The refineries that had no production of Jet A were not considered for the following evaluations.

ID	Brazilian Refineries	Jet A Production 2018 (Million m³)
1	Revap (SP)	1.93
2	Reduc (RJ)	1.43
3	Replan (SP)	1.13
4	Regap (MG)	0.71
5	Rlam (BA)	0.36
6	Repar (PR)	0.27
7	Refap (RS)	0.21
8	RPCC (RN)	0.20
9	Reman (AM)	0.13
10	RPBC (SP)	0.02
11	Riograndense (RS)	0
12	Lubnor (CE)	0
13	Manguinhos (RJ)	0
14	Recap (SP)	0
15	Rnest (PE)	0
16	Fasf (BA)	0
17	Univen (SP)	0
18	Dax Oil (BA)	0
19	Six (PR)	0



Source

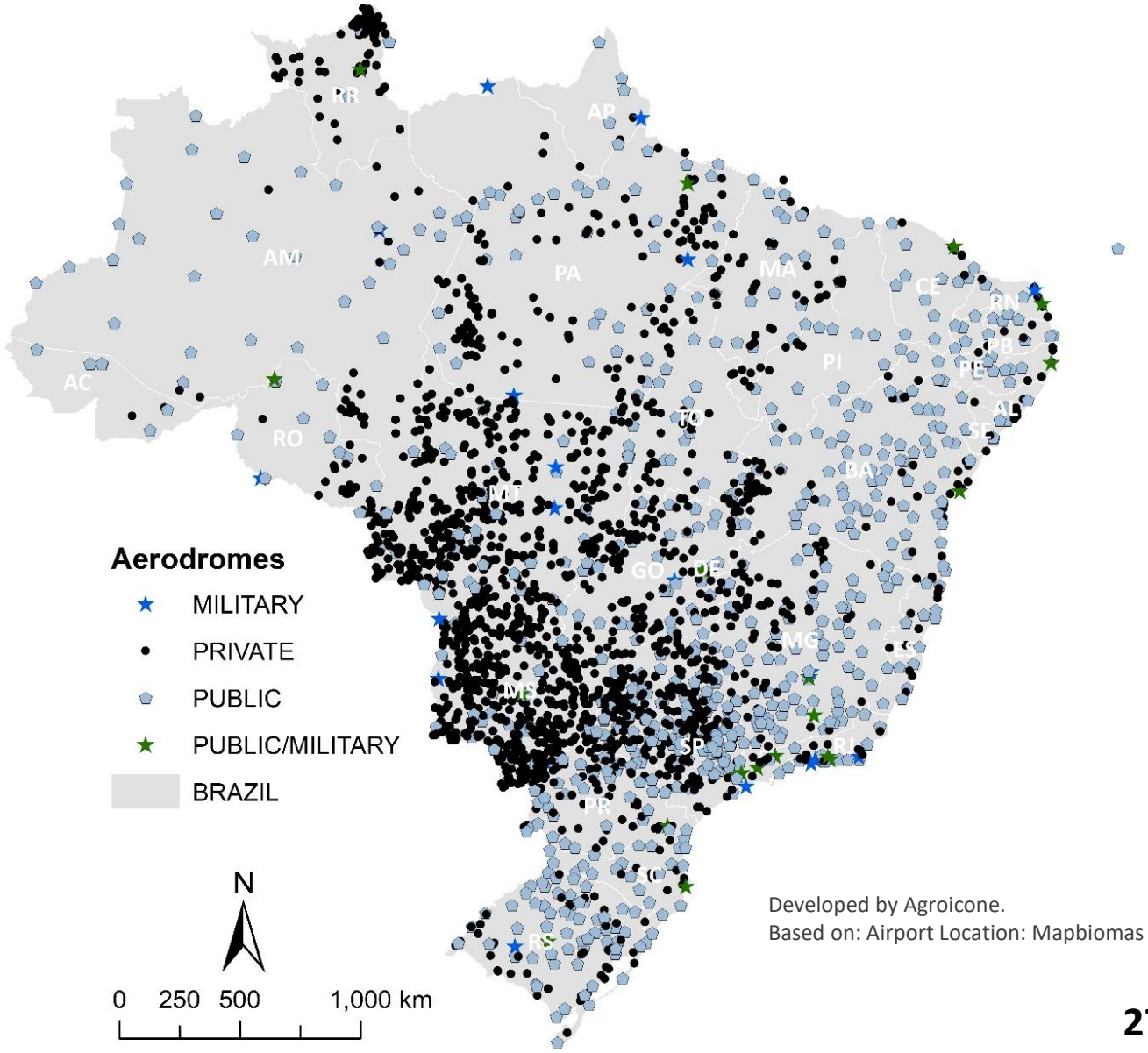
ANP (2019)

AIRPORTS LOCATION

Brazil has more than 2600 registered aerodromes, from those at least 650 are public, 1900 are private and 40 are military.

In 2018 ANAC (National Agency for Civil Aviation) registered the Jet A consumption of 143 airports, from which **34 are international airports**.

The ANAC database was used to categorize the International Airports.



Developed by Agroicone.
Based on: Airport Location: Mapbiomas (2018)

JET A CONSUMPTION AND AIRPORTS

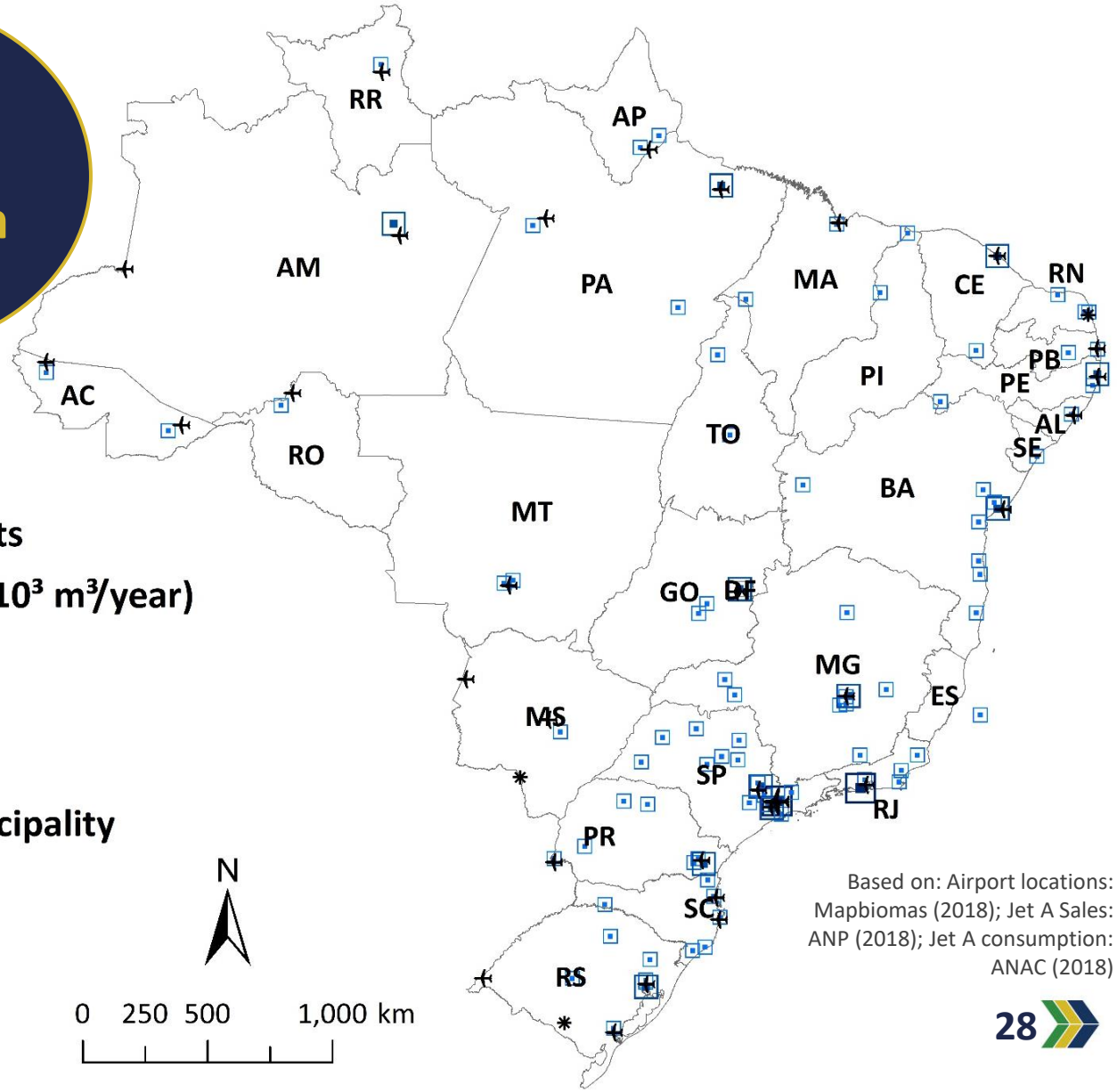
According to The Global Economy (2020), Brazil consumed an average of 123.46 thousand barrels per day of Jet fuel in 2018, whereas the world average, based on 43 countries, is 98.57 thousand barrels per day. Out of the 43 countries analyzed by this research group, Brazil is the 10th highest consumer of Jet fuel.

The consumption of Jet A was spatialized according to the fuel sales reported by ANP (2018).

In general, international airports are related to high regional consumption rates.

The **highest consumption** occurs in the **Southeast region**, which also holds the largest numbers of national and international flights. Around **58% of Jet A** sales are destined to SP State and RJ State.

Total sale of Jet A in Brazil in 2018
7.2 million liters



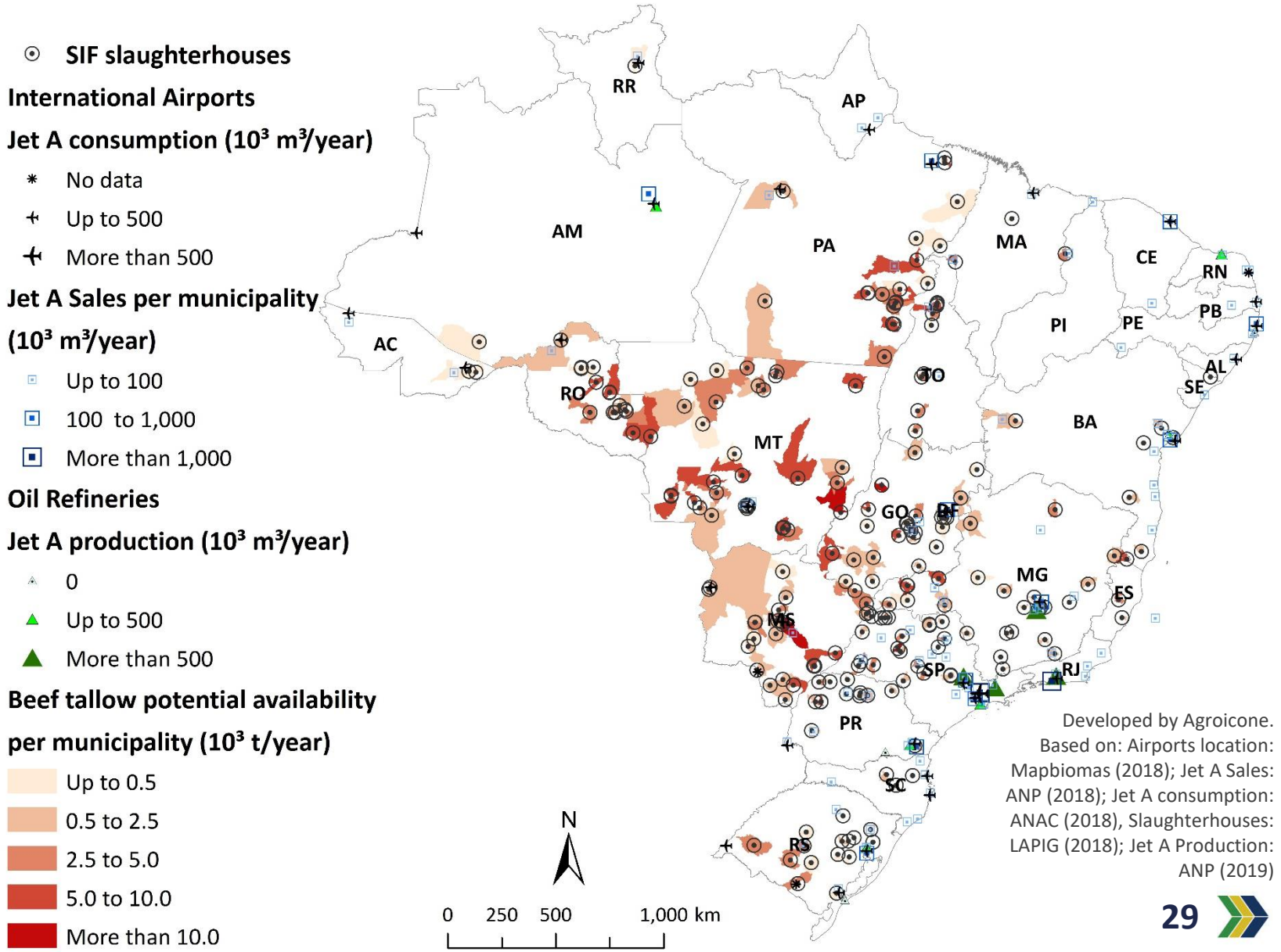
Based on: Airport locations: Mapbiomas (2018); Jet A Sales: ANP (2018); Jet A consumption: ANAC (2018)

MATCHING AVAILABILITY, PROCESSING AND DEMAND

This map shows the availability of beef tallow per municipality combining with processing sites – such as slaughterhouses with federal inspection (SIF) and oil refineries – and the consumption sites (airports).

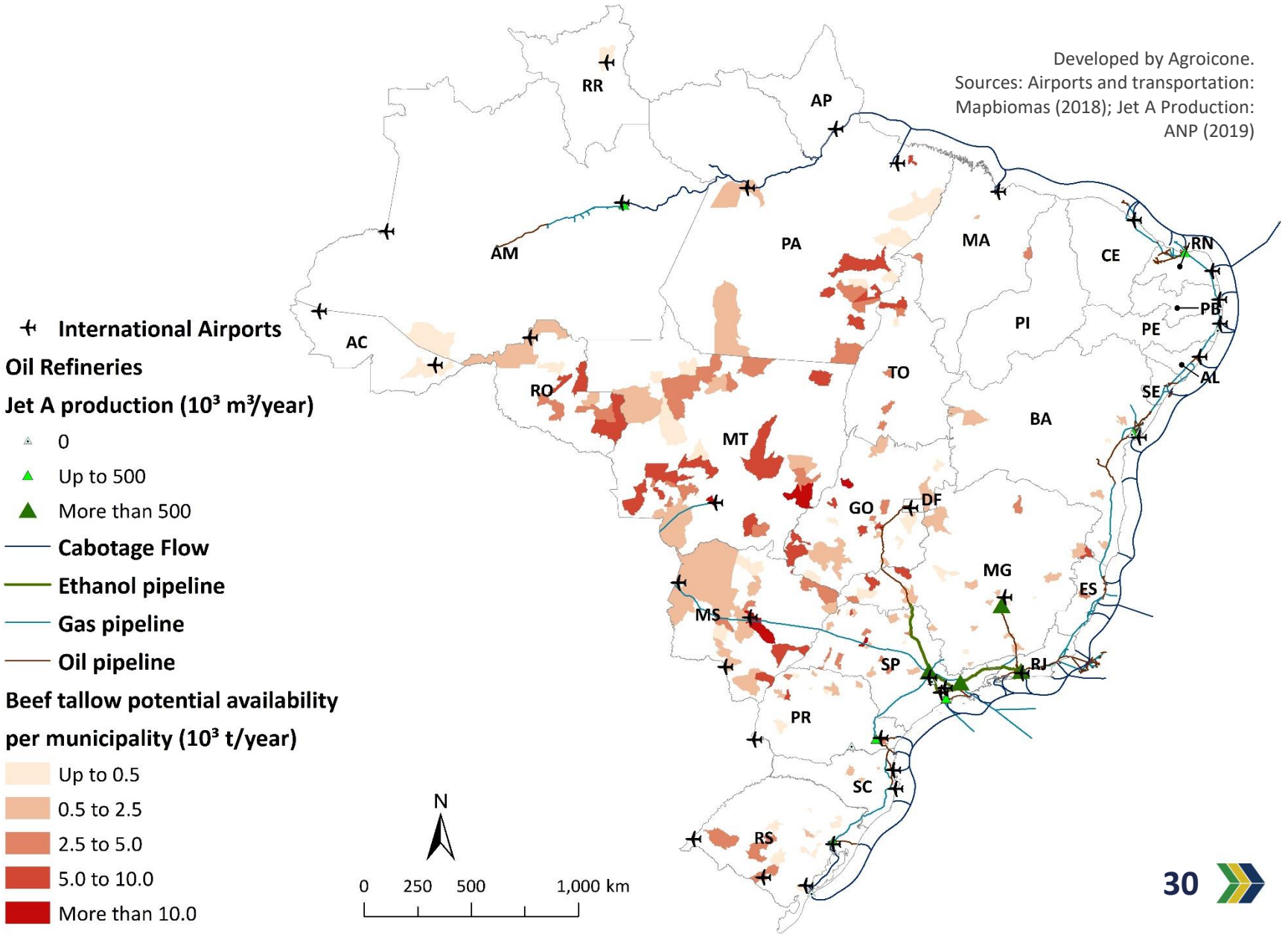
The feedstock availability is mostly concentrated in the North-Central region, while the oil refineries with the major consumers are mostly located in the Southeast region.

Therefore the logistics infrastructure is an important aspect to be considered for HEFA pathways based on beef tallow, including the possibility of supplying regional airports.

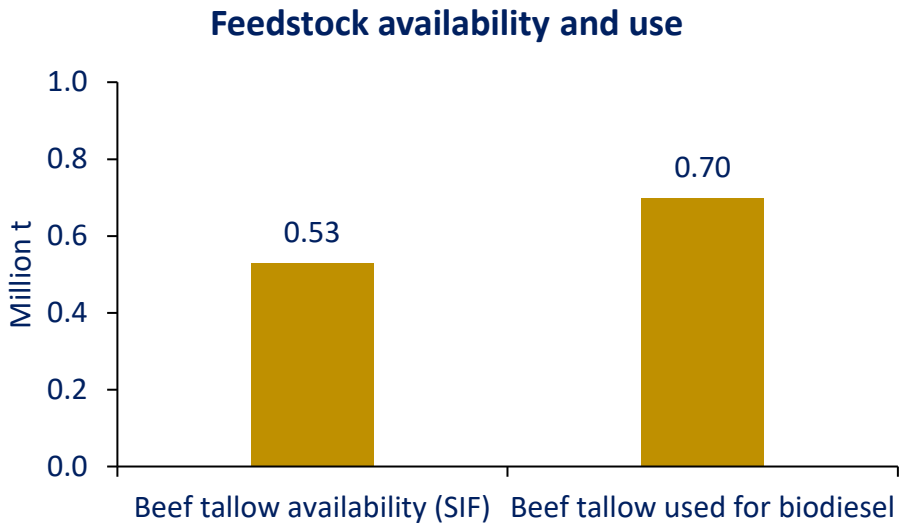


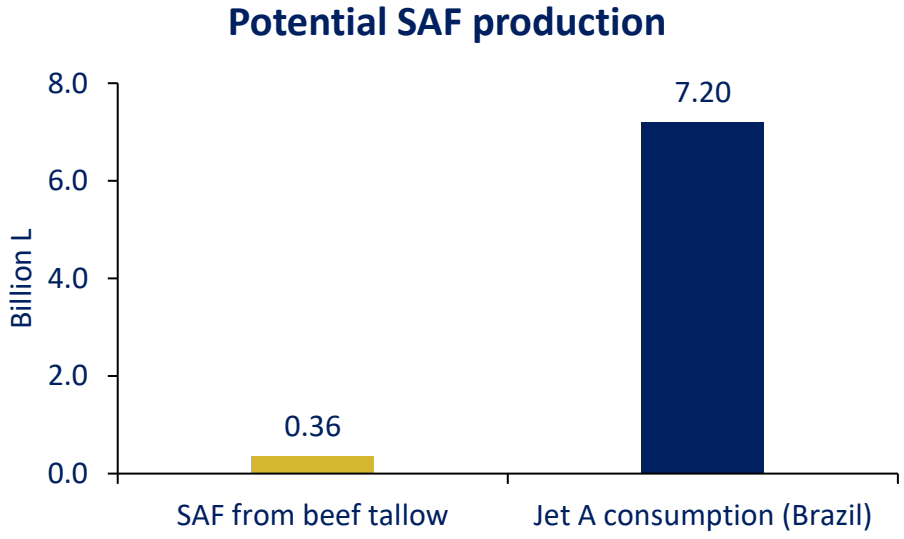
LOGISTICS AND INFRASTRUCTURE

According to this map, the gas pipeline could be used to supply natural gas to a HEFA plant eventually located in areas with high feedstock availability, such as in MS and MT States.



BEEF TALLOW AVAILABILITY AND SAF POTENTIAL



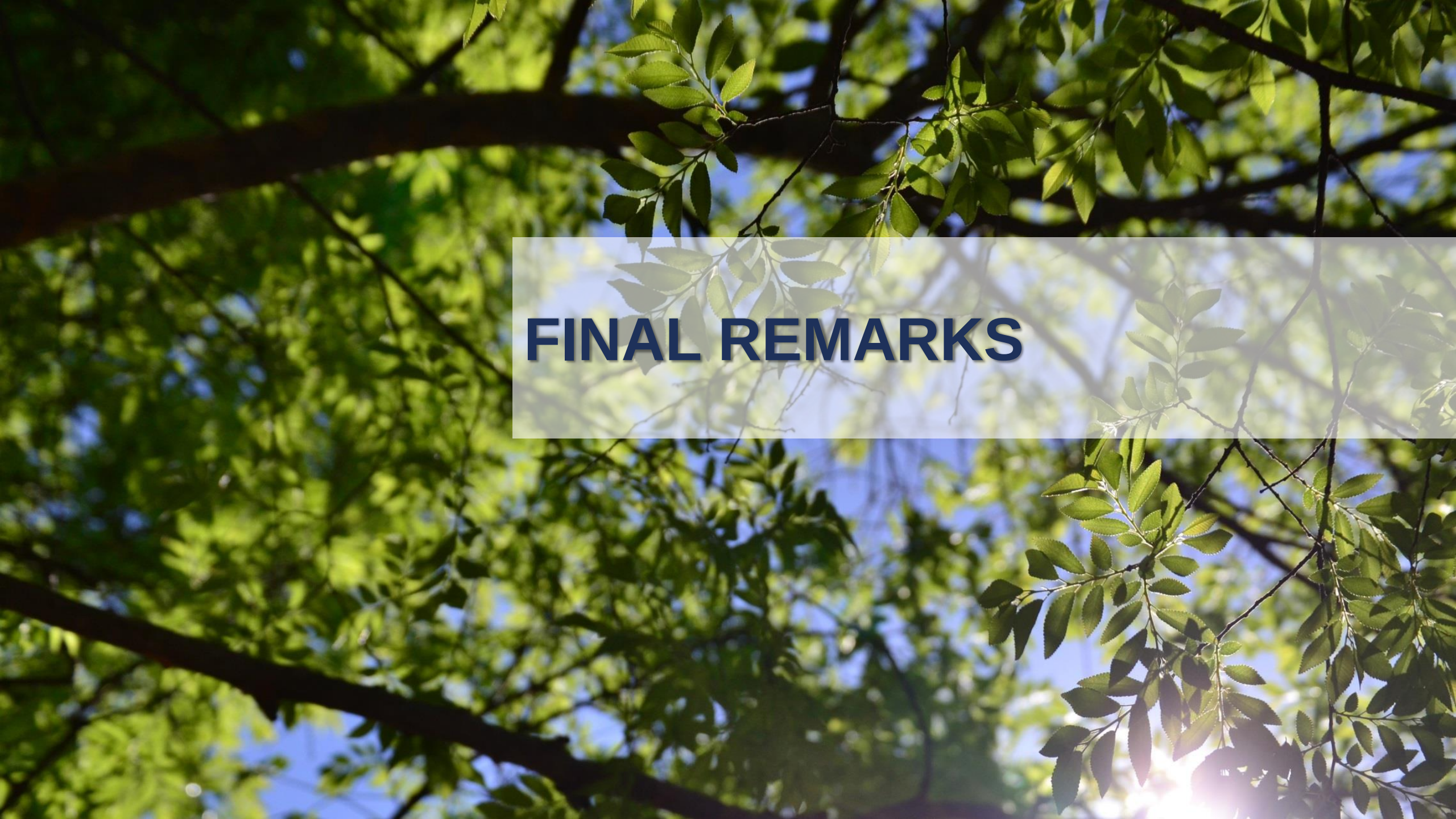


The amount of **beef tallow used for biodiesel production** is already **higher than all beef tallow** that could be recovered in slaughterhouses with federal inspection (SIF).

Furthermore, the use of tallow is not limited to biodiesel production, and there is a consolidated market for this feedstock (see slide 10).

The additional demand for beef tallow for SAF production could increase opportunity costs, impacting the economic feasibility and strategic purposes to use waste grease for producing aviation biofuels.

Beef tallow from slaughterhouses with international quality standards could supply around **5%** of the total demand of Jet A.



FINAL REMARKS

KEY-MESSAGES

- This project has made a significant effort to build a **database** on the availability of beef tallow, with significant geographical detail at national level for Brazil. The data is **available in an online platform,** with functionalities to download information for research and within the interest of investors.
- There are many advantages of using beef tallow as a feedstock for SAF production, although it is important to consider that this residue is already being used for other purposes, such as biodiesel production, cleaning products and animal nutrition. It might enhance the competition for this residue, causing an increase in the opportunity cost.
- Ideally, beef tallow should be collected from slaughterhouses with federal inspection (SIF), once these places concentrate the feedstock that already complies with international quality standards. Such slaughterhouses correspond to around 77% of the total formal beef market in Brazil.
- Under these conditions, the availability of beef tallow is mostly located in the **Midwest region (45%).** The **MT State** represents 22% of all beef tallow availability in Brazil, followed by **MS (12%)** and **SP (12%)** States.
- Beef tallow from slaughterhouses with international quality standards could supply around **5.0% of the total demand of Jet A** in Brazil.
- HEFA plants require a large amount of hydrogen, thus it would be interesting to consider its location close to the oil refineries. Refineries are mostly located in the Brazilian coastline, which is far from regions with high availability of beef tallow. Furthermore, most of Jet A consumption is also located in the coastline, particularly in Brazil's Southern and South regions.
- Building HEFA plants close to gas pipelines could be an alternative for supplying **regional consumers** – which also includes airports with international flights – near areas with high feedstock availability, such as in MS State.
- Considering beef tallow processing using biomethane, as energy source, or hydrogen from water electrolysis is a possibility that was not analyzed in this report and deserves further investigation.

NEXT STEPS

- The project has not performed analysis on issues that deserve to be further investigated, such as:
  - Cost evaluation
  - Life Cycle evaluation
  - Optimization of logistics
  - Integration with other feedstock and with other fuels.

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ANNEX1 – Methodological supplement

Information, with high quality, regarding beef tallow availability is scarce in literature, especially at a fine scale. Furthermore, the level of informal market for beef is significant (around 17%).

Only slaughterhouses with Federal Inspection Systems (SIF) are authorized to sell products to the international market. Beyond having higher quality standards, such slaughterhouses are usually bigger, representing 77% of the Brazilian formal market for beef and have higher traceability capabilities. In this context, it was decided that the study should focus on beef tallow availability in SIF slaughterhouses.

The exact location of slaughterhouse has been mapped based on GIS statistics. However, information on the availability per slaughterhouse is limited. And processing capacities are reported using idiosyncratic range values. Such ranges do not allow for an accurate representation of their effective processing capacity, particularly due to “open” upper limits. Such upper limits do not allow for the differentiation of capacity larger than 10,000 t/year.

This project has tested several datasets available on State level and municipality level (number of slaughterhouses, number of jobs related to cattle slaughter, expert opinion for the upper limits of SIF capacity) to serve as an “instrument” or to converted the State level data (that has good quality) to information by municipality. The number of jobs related to cattle slaughters per State was the one with better statistical fit. It was further used to allocate the SIF tallow production on State level to municipalities where, at least, one SIF slaughterhouse was identified through GIS processing.

In each state “S”, the following rule was applied for all municipalities with, at least, one SIF slaughterhouse:

$$Ti = bi/BS*Ts$$

“Ti” is the tallow availability in municipality “i“;

“bi” is the number of job related to slaughterhouses in municipality “i”;

“BS” is the sum of all jobs related to slaughterhouses in all municipalities with at least one SIF slaughterhouse

“Ts” is the total tallow availability in SIF slaughterhouse per State, calculated based on official statistics.

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