Required logistical resources to support the development of a sustainable corn stover bioeconomy in the USA

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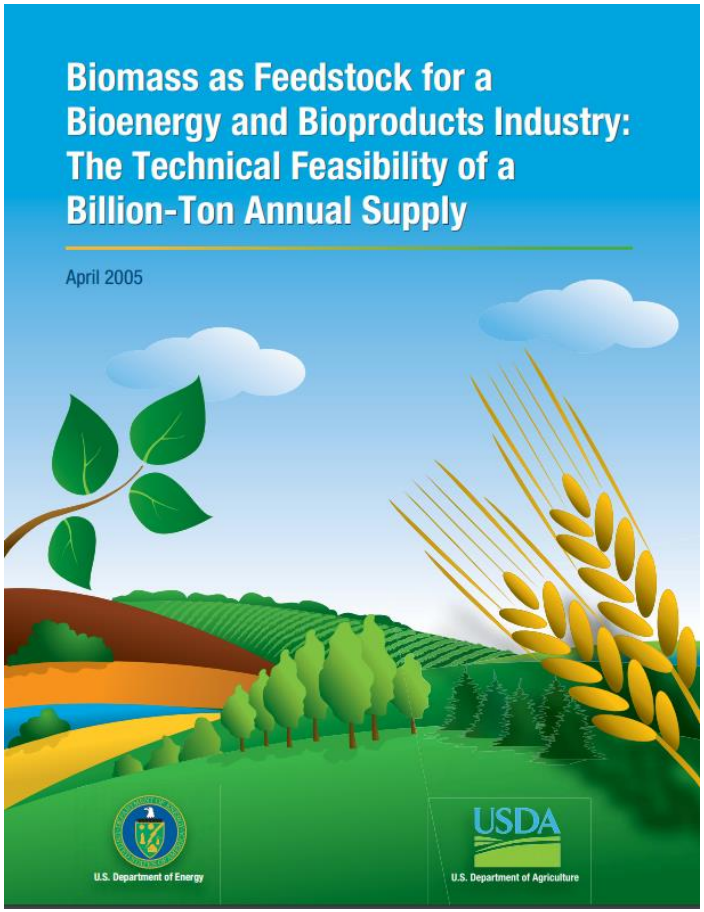
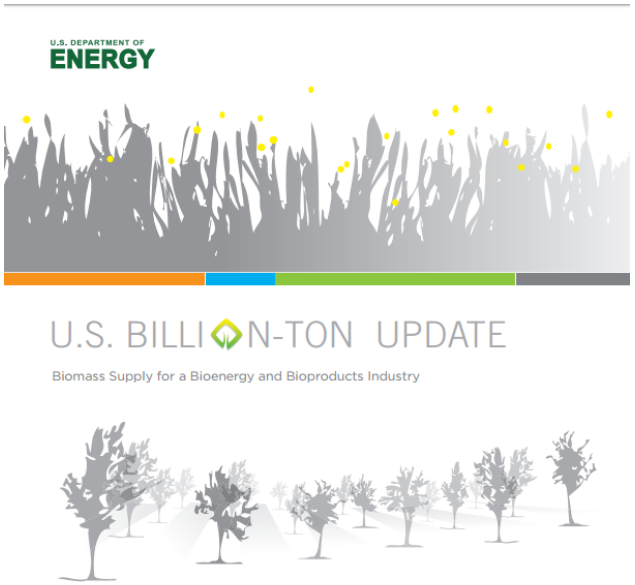
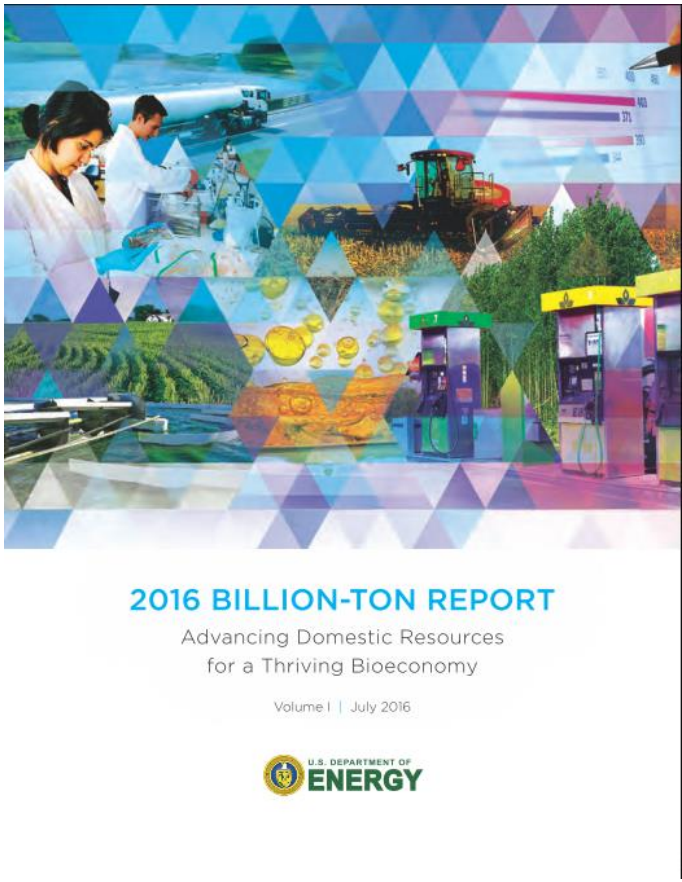
Drivers: Development of the bioeconomy

- **Energy security**
- **GHG reduction and decarbonization of industrial activities**
- **Increased economic activities and jobs in rural areas and remote communities**

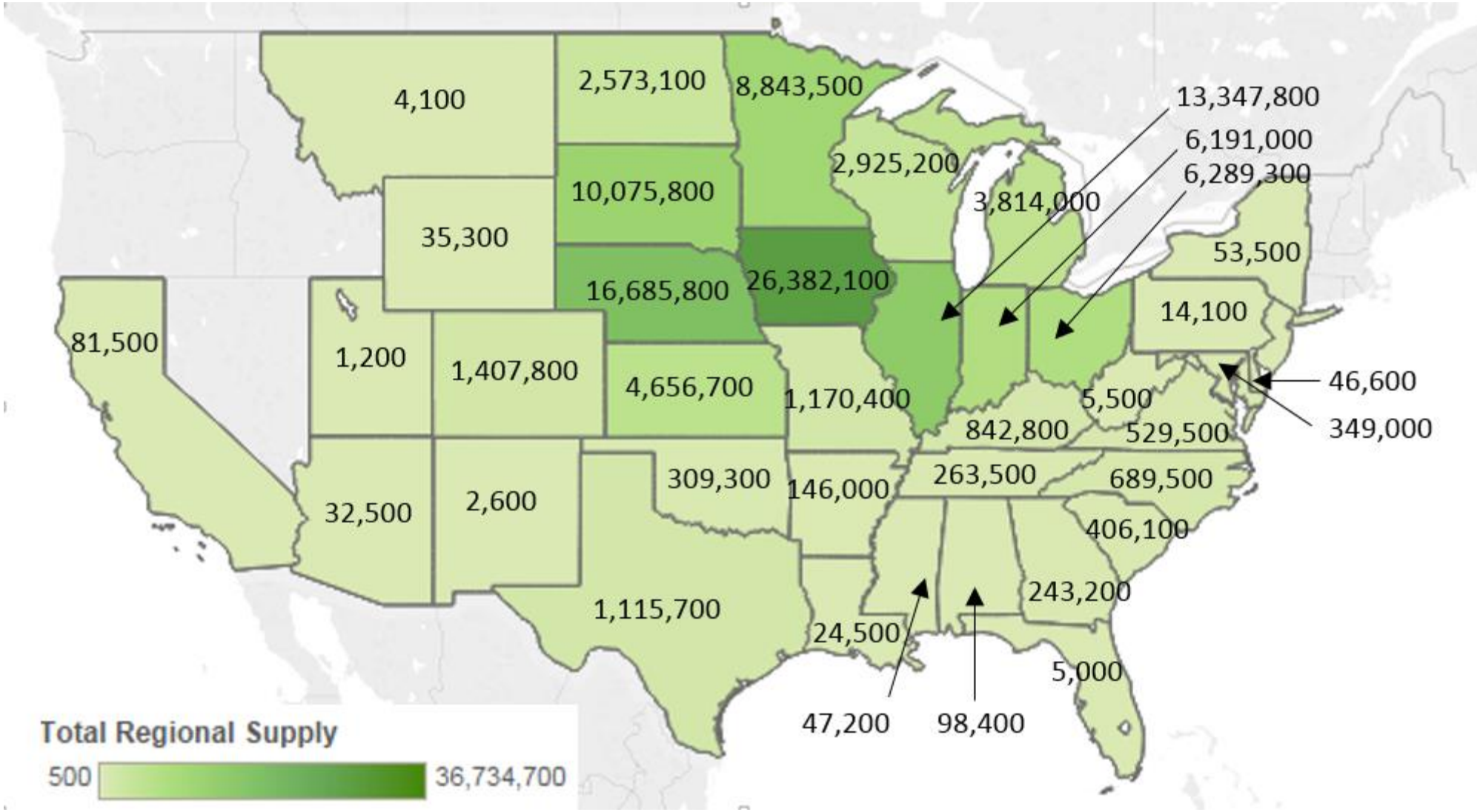
U.S. Billion Ton Studies- 2005, 2011 and 2016







Corn stover availability in the USA (dry tons)



Source: Hilliard, 2016-ORNL

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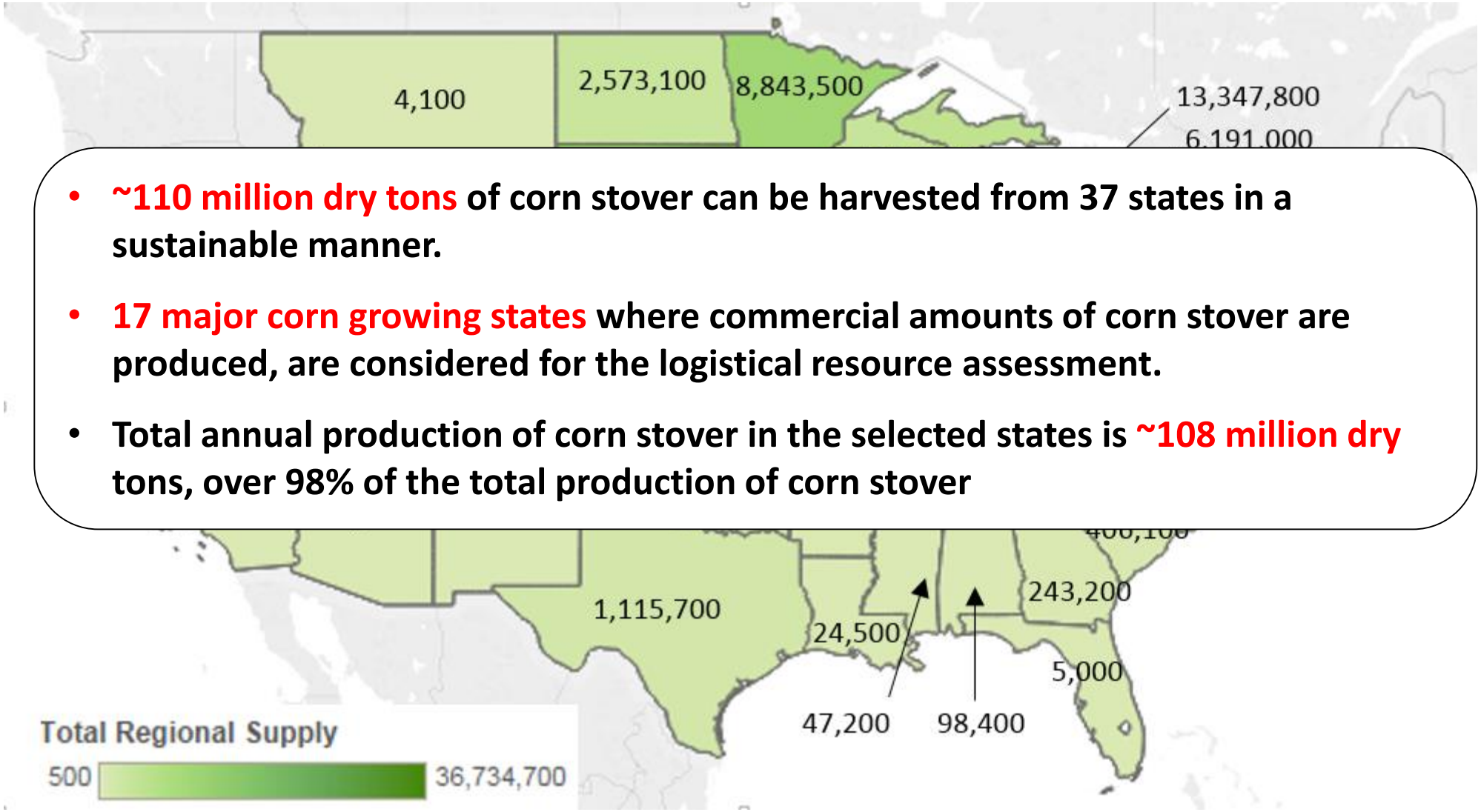


- **~110 million dry tons of corn stover can be harvested from 37 states in a sustainable manner.**
- **17 major corn growing states where commercial amounts of corn stover are produced, are considered for the logistical resource assessment.**
- **Total annual production of corn stover in the selected states is ~108 million dry tons, over 98% of the total production of corn stover**

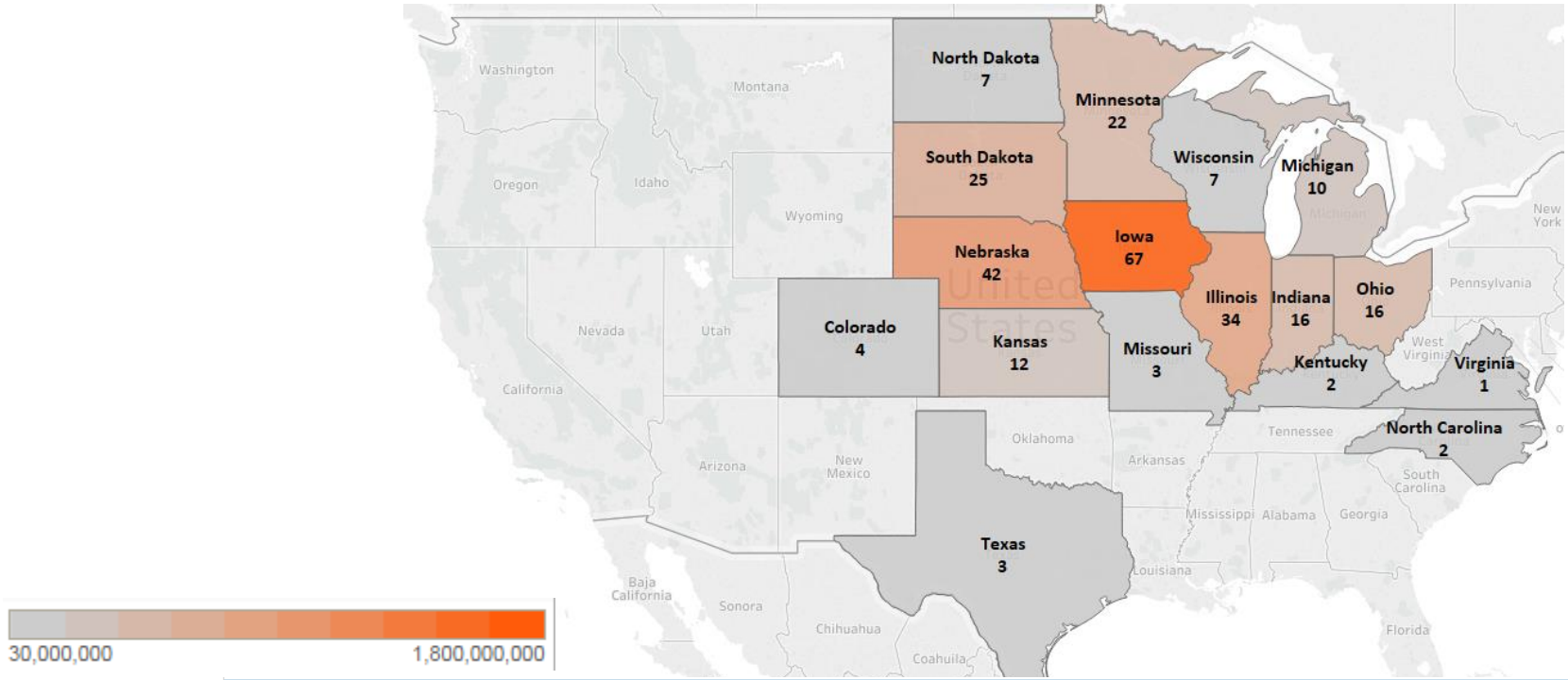
Source: Hilliard, 2016-ORNL

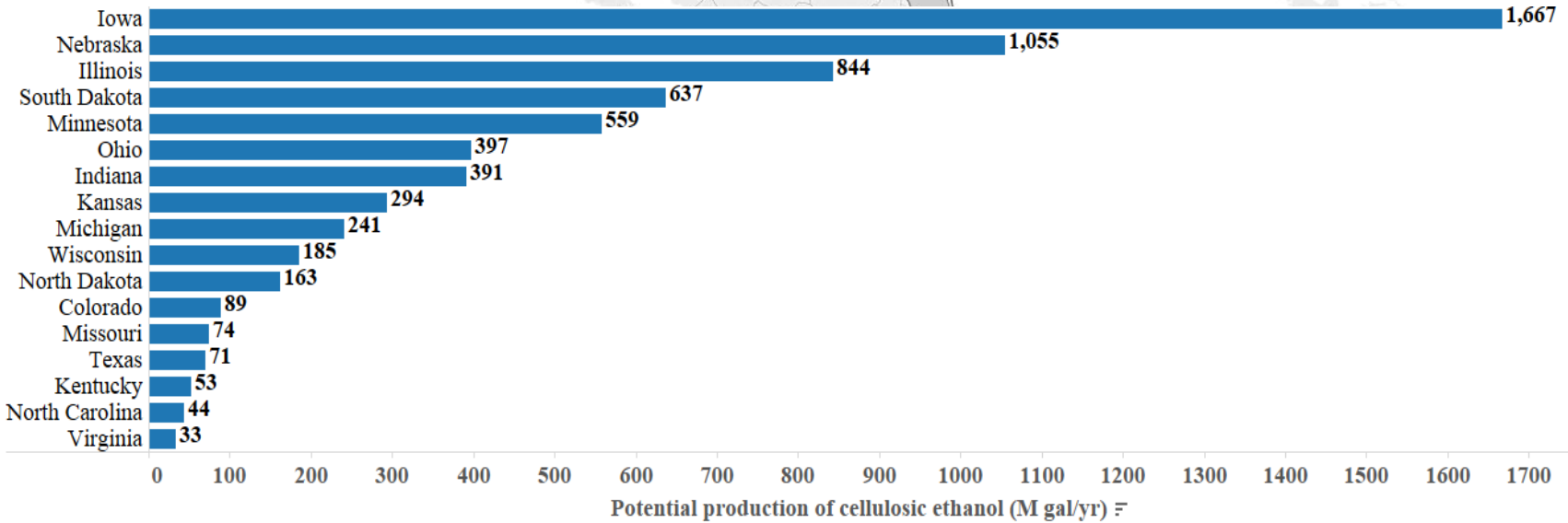
Biorefinery Profile

General profile of a commercial-scale cellulosic ethanol plant modeled in IBSAL-MC	
Annual ethanol production capacity	25 million gallons
Conversion yield	79 gallons/dry ton
Annual corn stover demand	315,000 dry tons
Operating days in a year	330 days
Daily corn stover demand	950 dry tons
Average harvestable yield	2 dry tons/ac
Supply radius	30 miles
Farm participation rate (ratio of contracted corn acres to the total corn acres in the supply radius)	23%
Ratio of total corn acres to total crop acres in the supply radius	45%
Average length of the harvest season	75 days
Average number of days suitable for fieldwork within the harvest season	55 days (5 days per week)
Working hours in a day	10 hours
Percentage of the total time to mobilize logistics equipment between corn fields (unproductive time)	20%
Maximum time that collected bales can be temporarily stored at the roadside of corn fields	2 months

Sources: DuPont, 2014; Shah, 2013; Gutesa, 2013; Humbird et al., 2011; Hilliard, 2016; USDA, 2010.

Potential number of cellulosic ethanol plants





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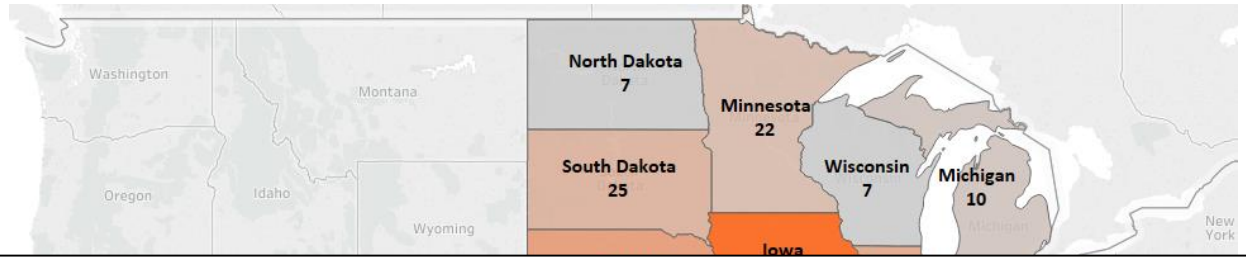
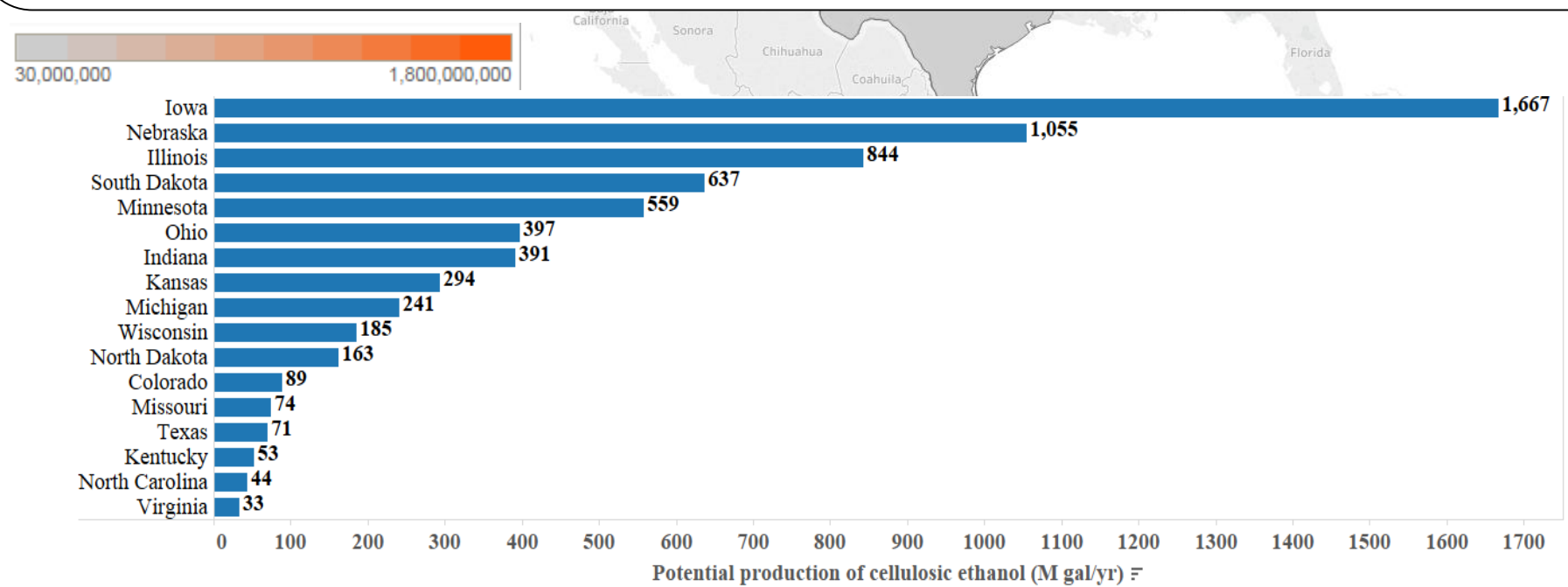


- **Total potential production of ethanol in these states is estimated to be 6.8 billion gallons per year**
- **Total number of ethanol plants is estimated to be 272.**



Logistical resources- corn stover

Corn stover chopper/shredder

Baler

Bale collector /stacker

Tractor (180-220hp)

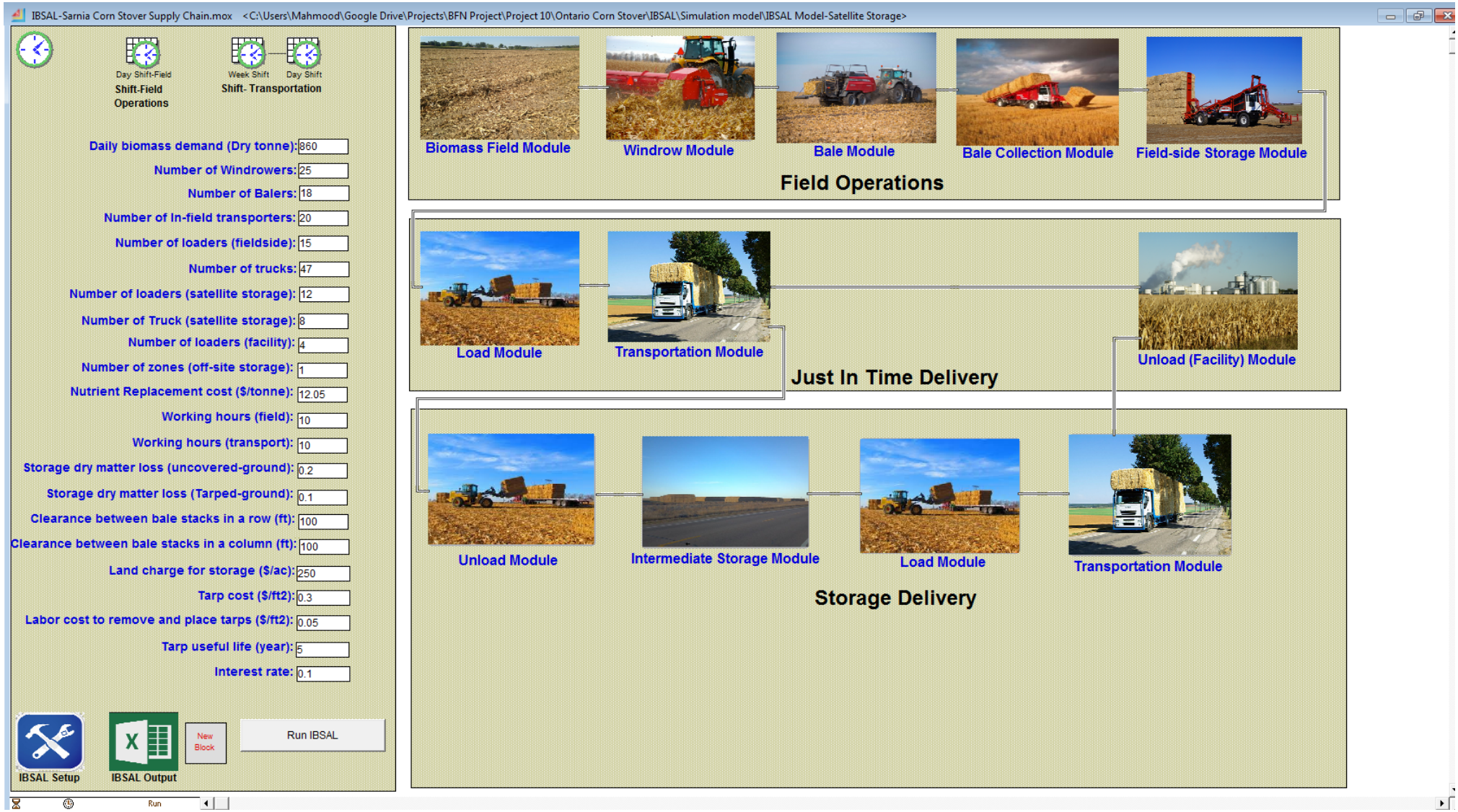
Truck and trailer

Loader

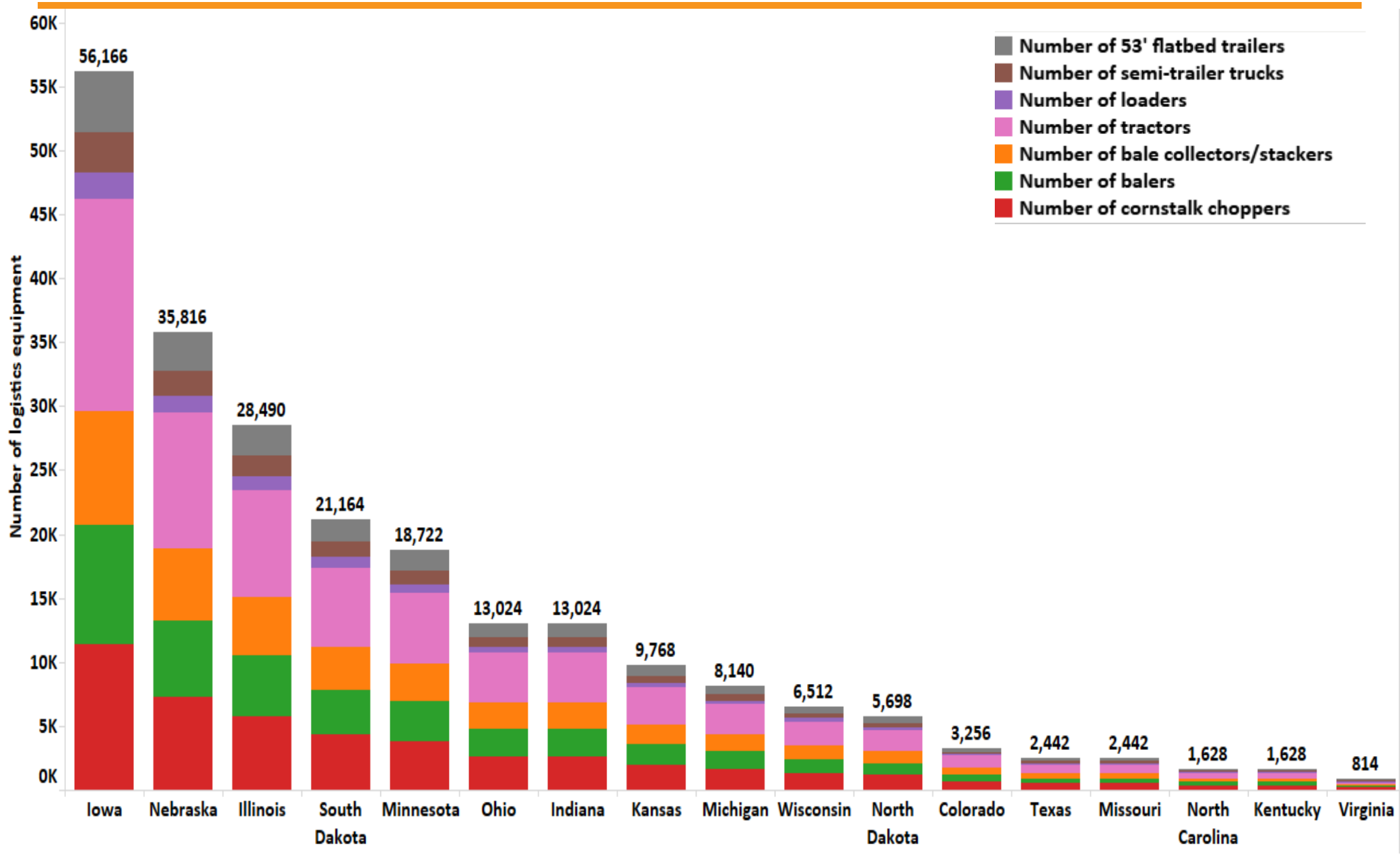
Storage

Sources: Stinger Inc., 2016; Morris-industries, 2014; Shah, 2013; Gutesa, 2013.

Snapshot of the IBSAL model for logistics resource assessment

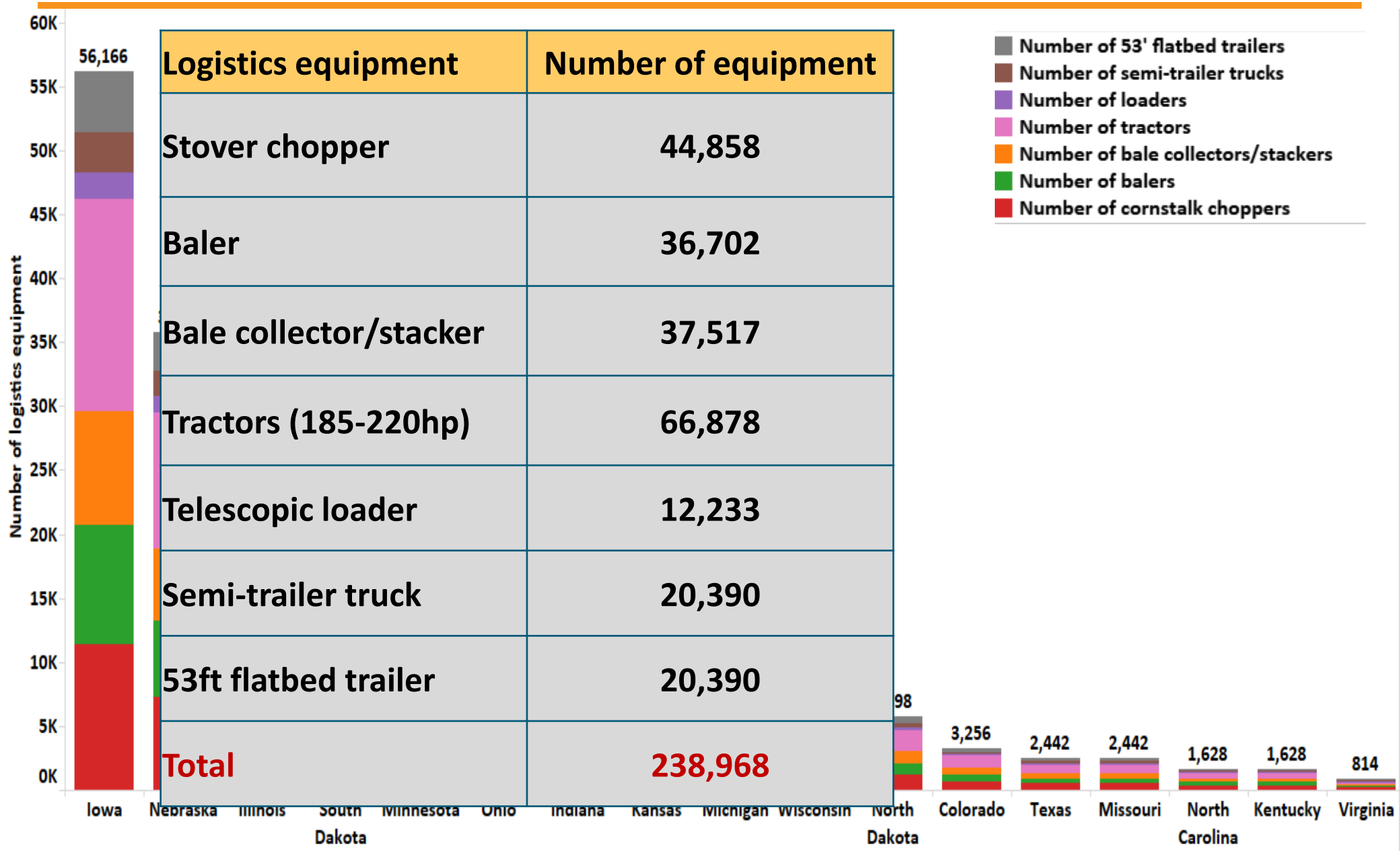


Number of logistics equipment

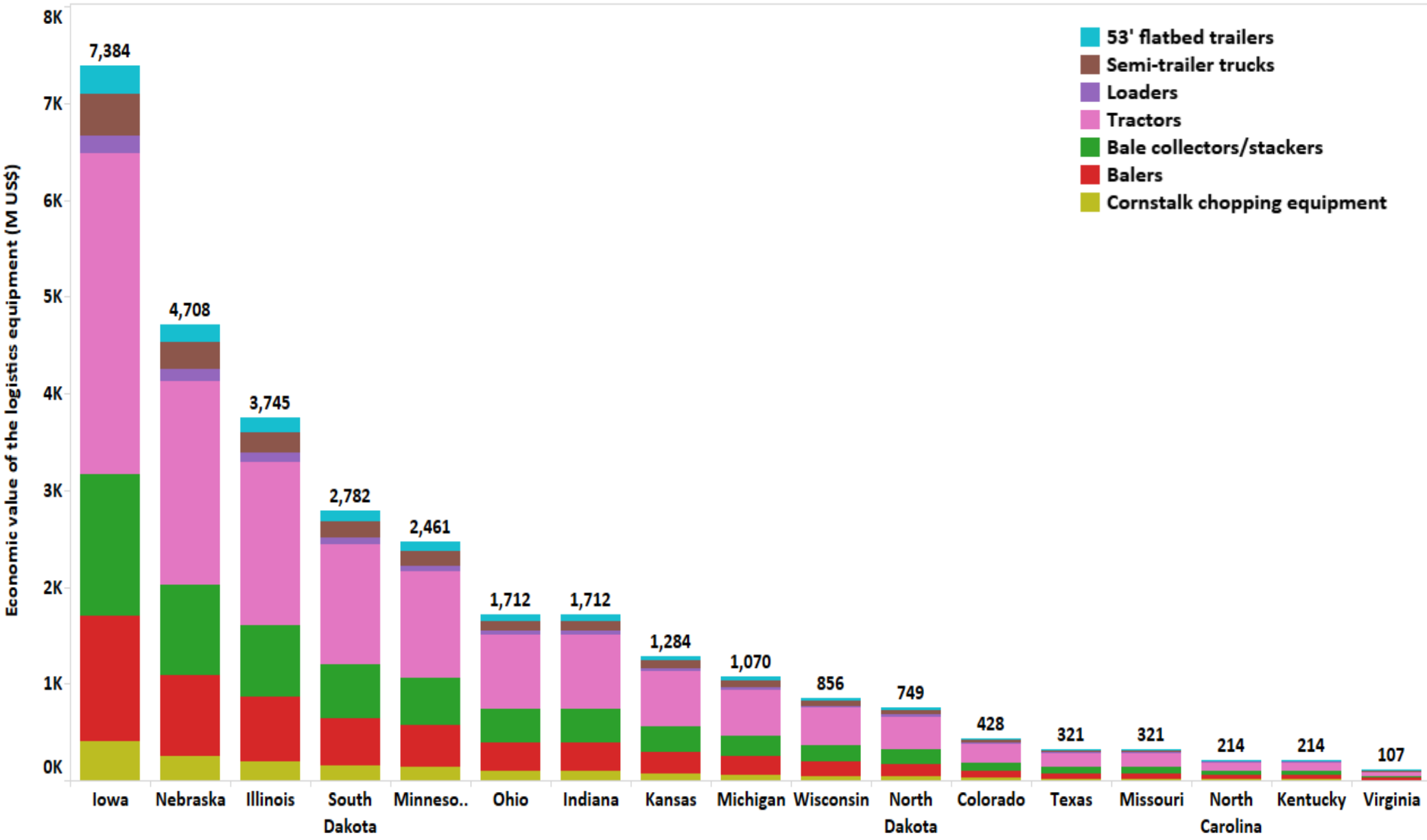


Number of logistics equipment

Logistics equipment	Number of equipment
Stover chopper	44,858
Baler	36,702
Bale collector/stacker	37,517
Tractors (185-220hp)	66,878
Telescopic loader	12,233
Semi-trailer truck	20,390
53ft flatbed trailer	20,390
Total	238,968

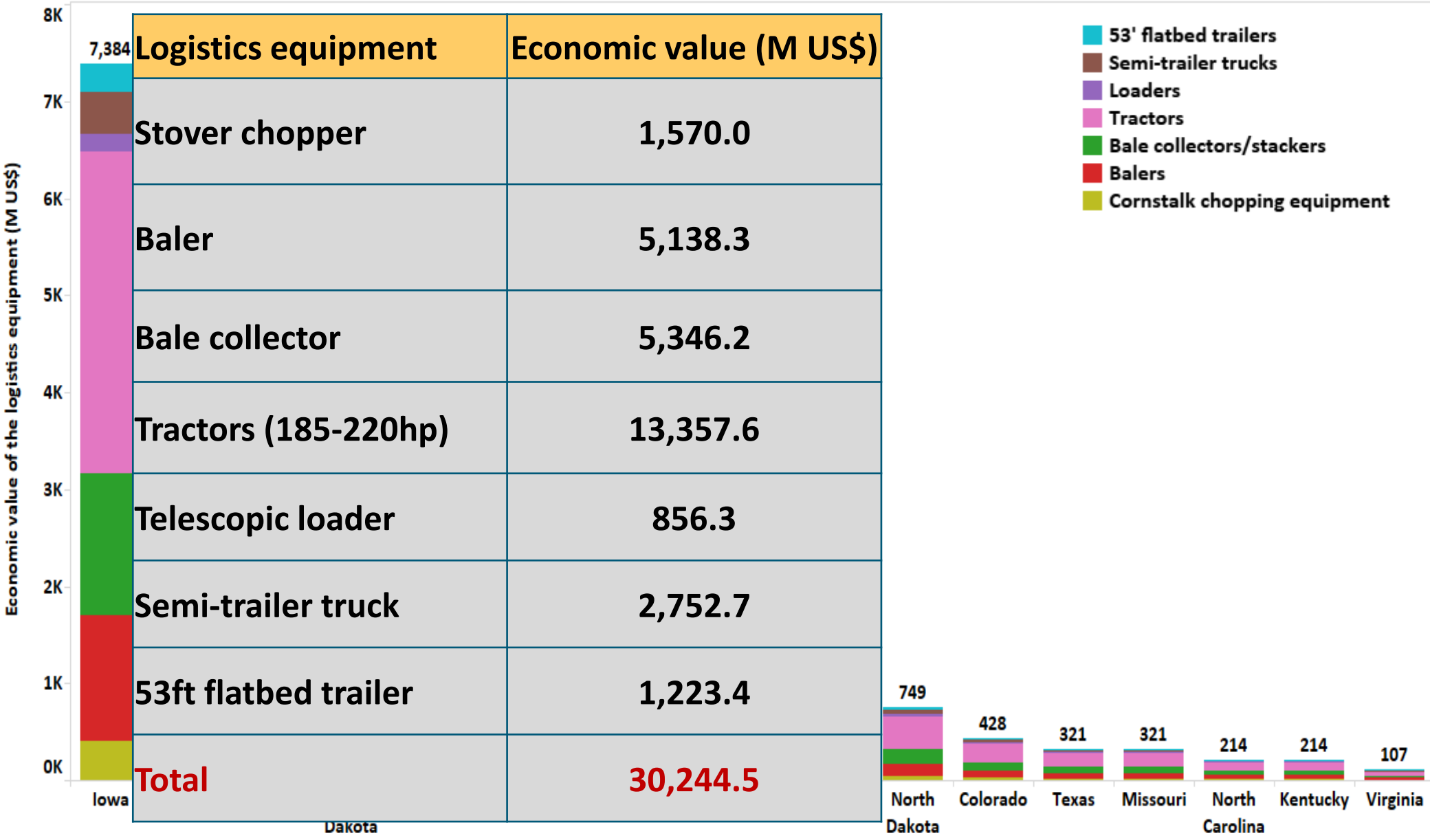


Economic values of the logistics equipment (million US$)

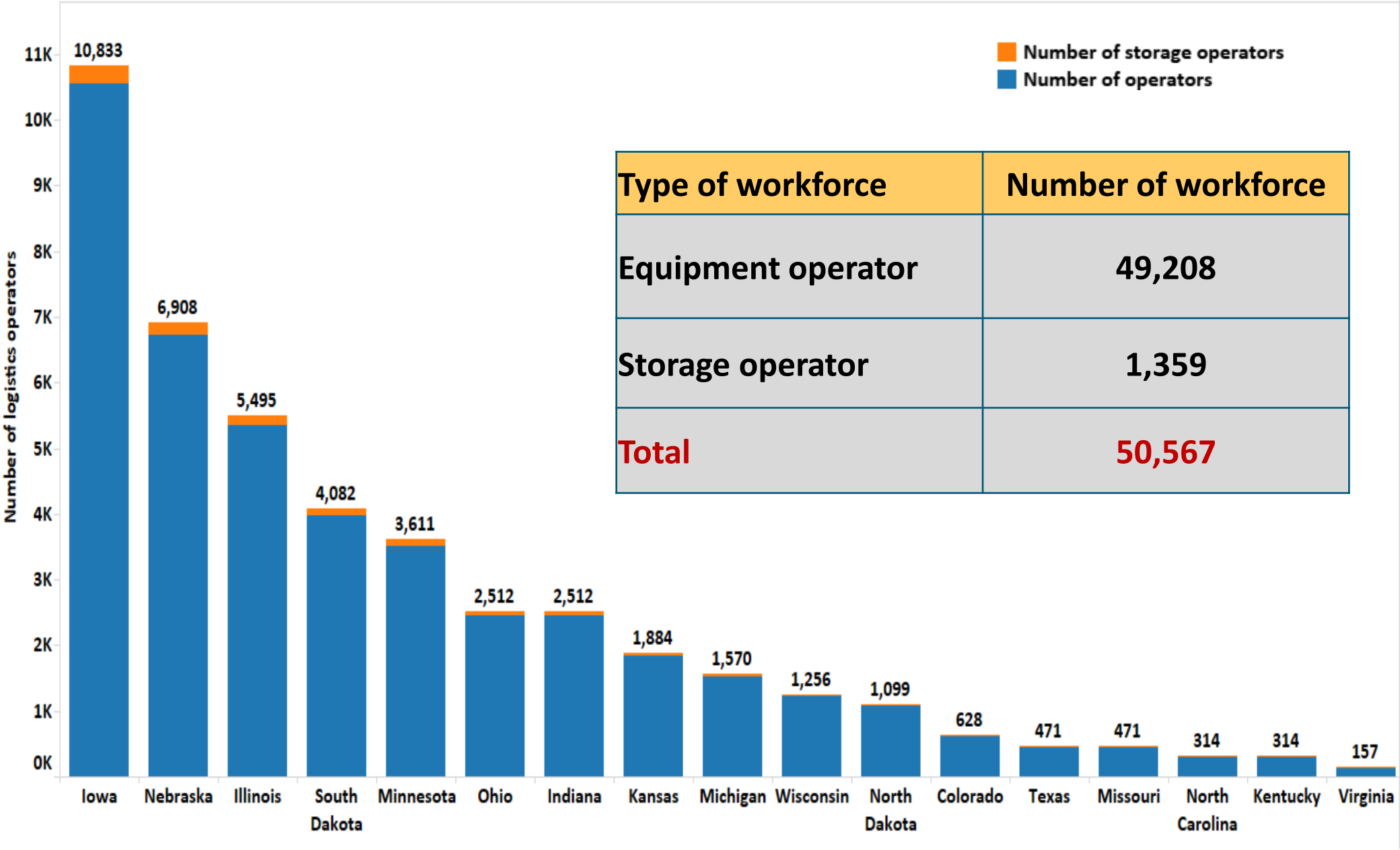


Economic values of the logistics equipment (million US$)

Logistics equipment	Economic value (M US$)
Stover chopper	1,570.0
Baler	5,138.3
Bale collector	5,346.2
Tractors (185-220hp)	13,357.6
Telescopic loader	856.3
Semi-trailer truck	2,752.7
53ft flatbed trailer	1,223.4
Total	30,244.5

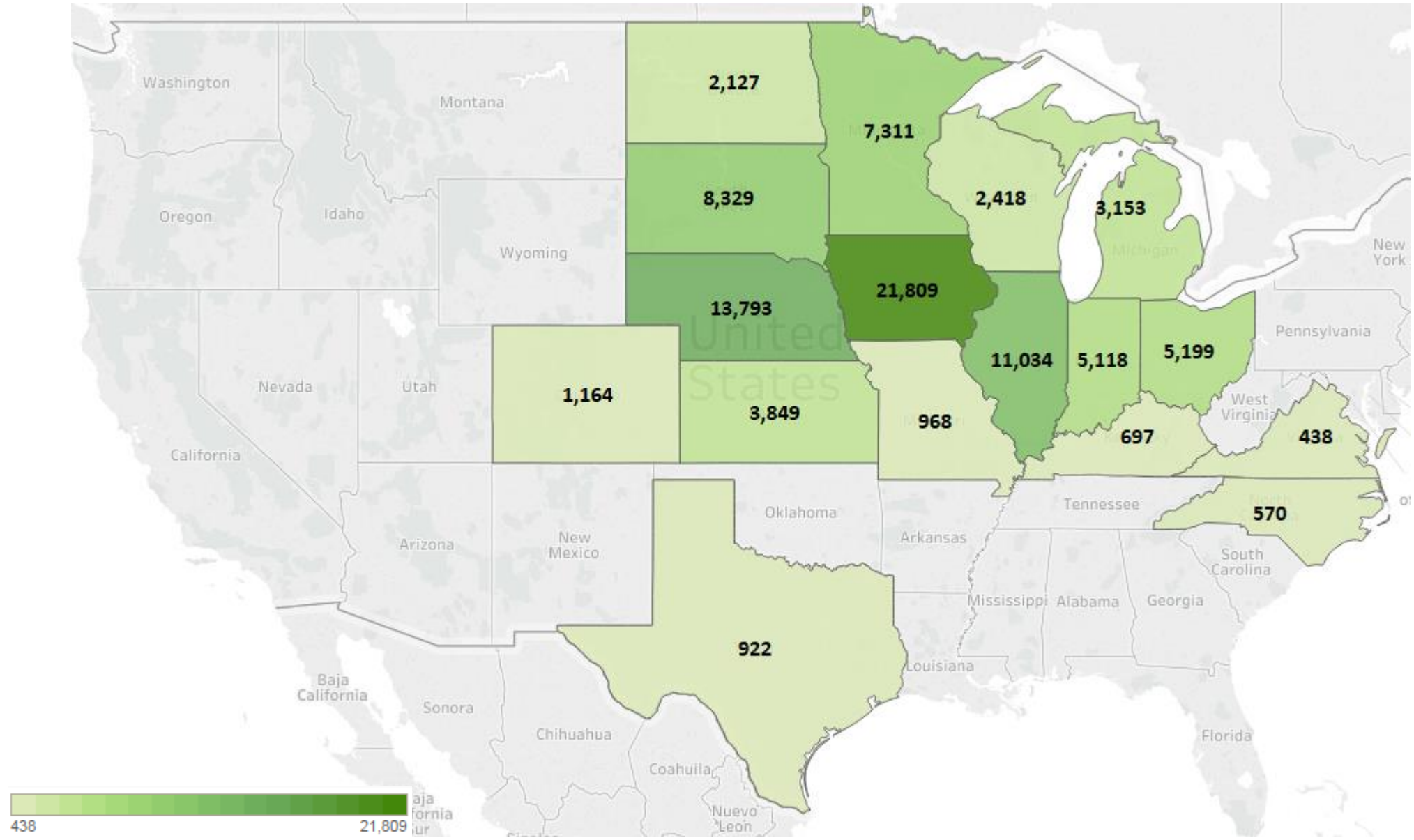


Number of logistics operators



Type of workforce	Number of workforce
Equipment operator	49,208
Storage operator	1,359
Total	50,567

Number of contracted corn growers



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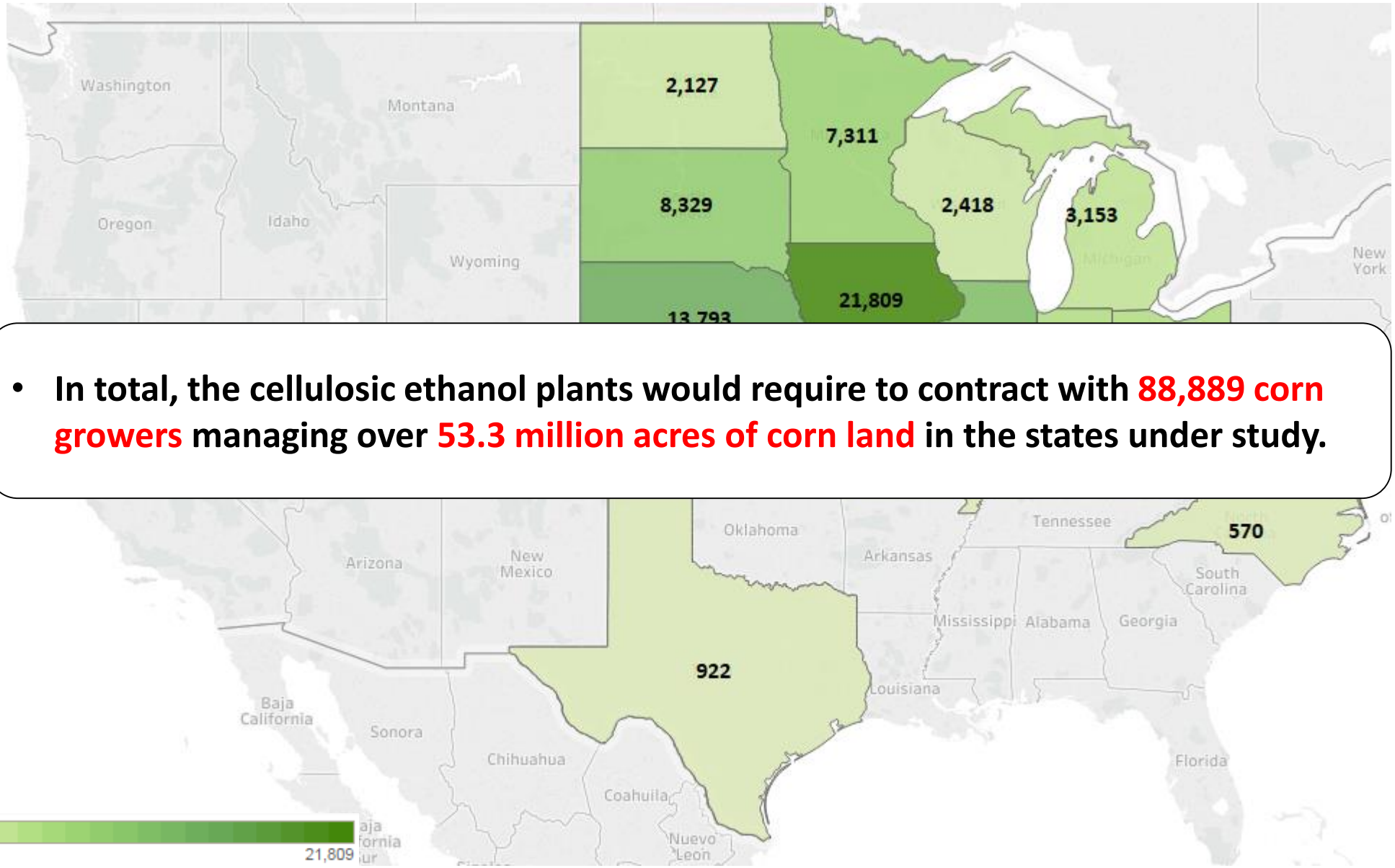
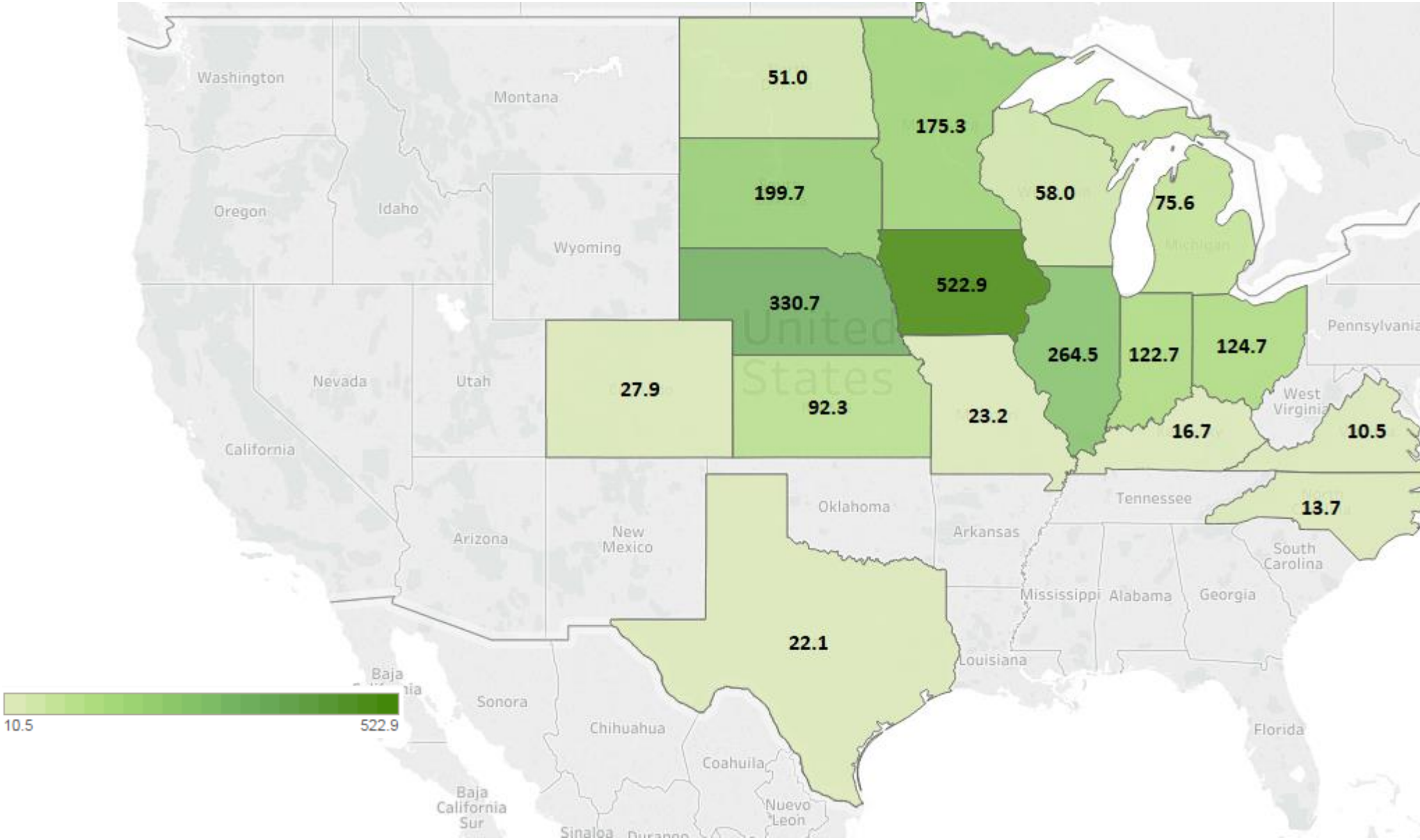


- **In total, the cellulosic ethanol plants would require to contract with 88,889 corn growers managing over 53.3 million acres of corn land in the states under study.**

Net income of corn growers (million $US)



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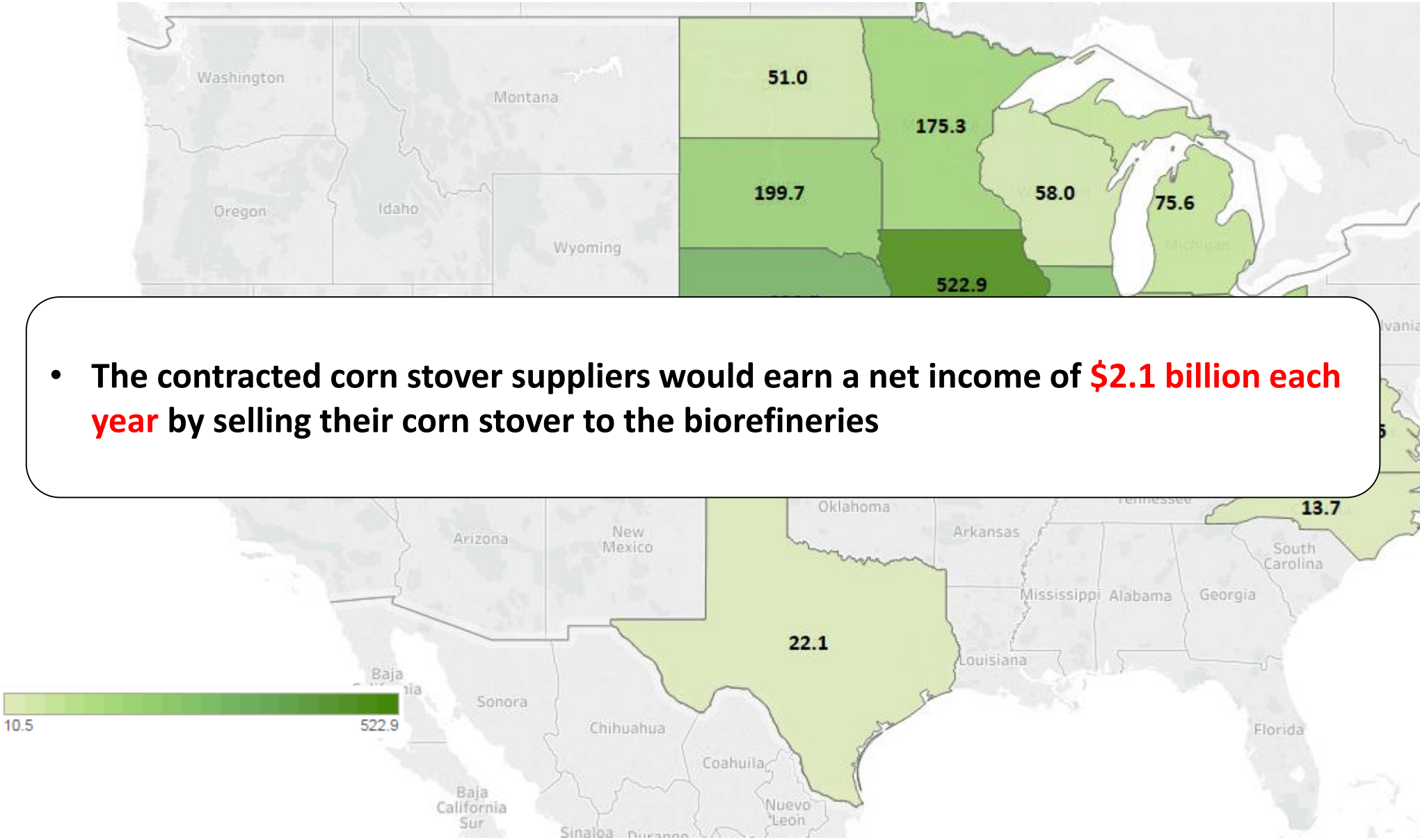


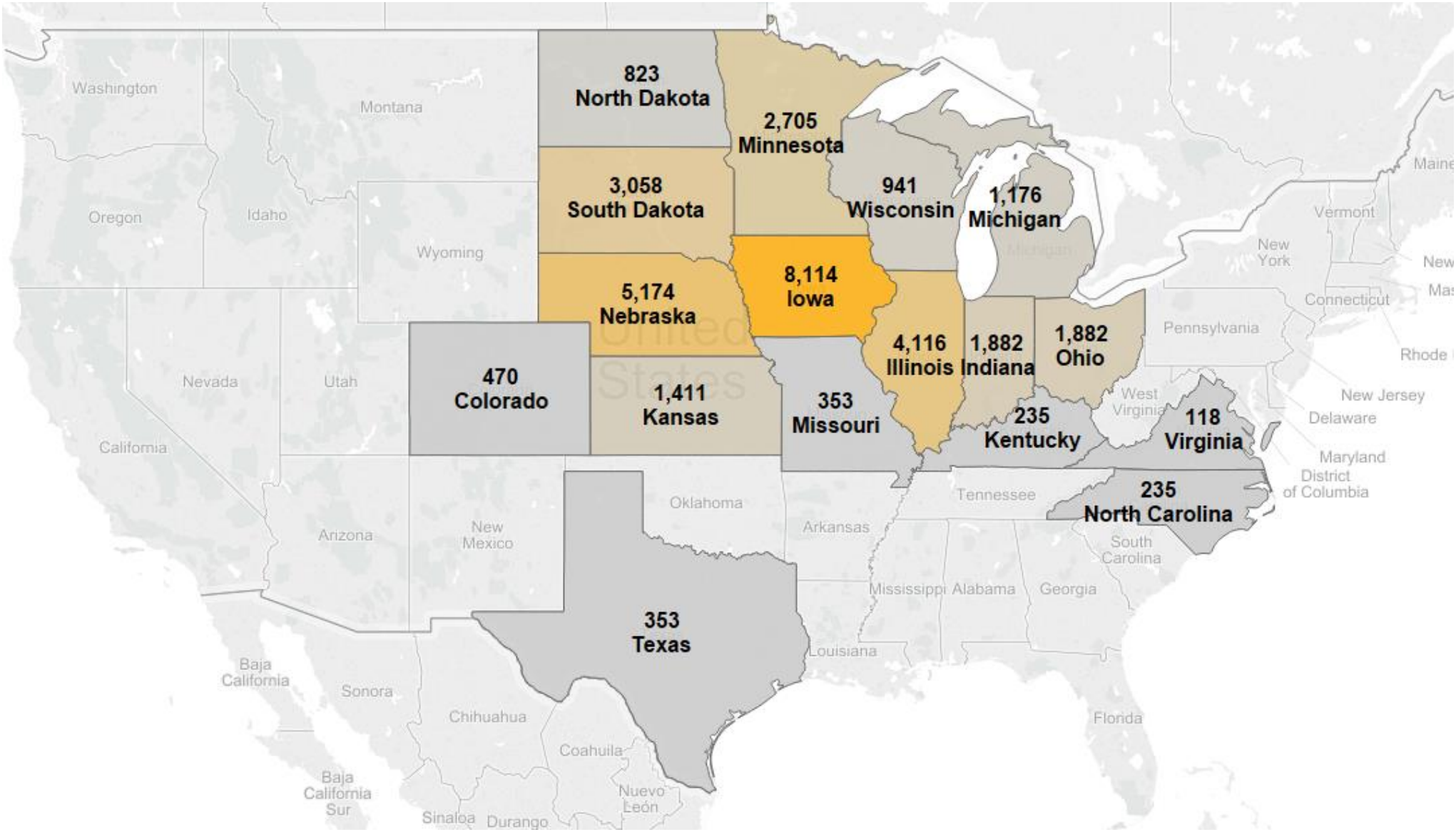
- **The contracted corn stover suppliers would earn a net income of $2.1 billion each year by selling their corn stover to the biorefineries**

Storage configuration

Intermediate storage configuration for a 25 MGY cellulosic ethanol plant	
Maximum inventory level at each intermediate storage site	30,000 dry tons
Maximum number of stored bales	66,244
Average bale density	10.4 lb/ft^3
Bale size	3×4×8 ft
Stack configuration	6 high, 6 wide and 60 long
Number of bales in each stack	2,160
Number of stacks in each storage site	31
Clearance between two adjacent stacks in a row (ft)	48
Clearance between two adjacent stacks in a column (ft)	72
Size of each intermediate storage (ac)	18.56
Total land requirement (ac)- seven storage sites	129.92

Sources: Martinez-Kawas, 2013; Shah, 2013;

Land requirement (ac) to store bales after harvest season



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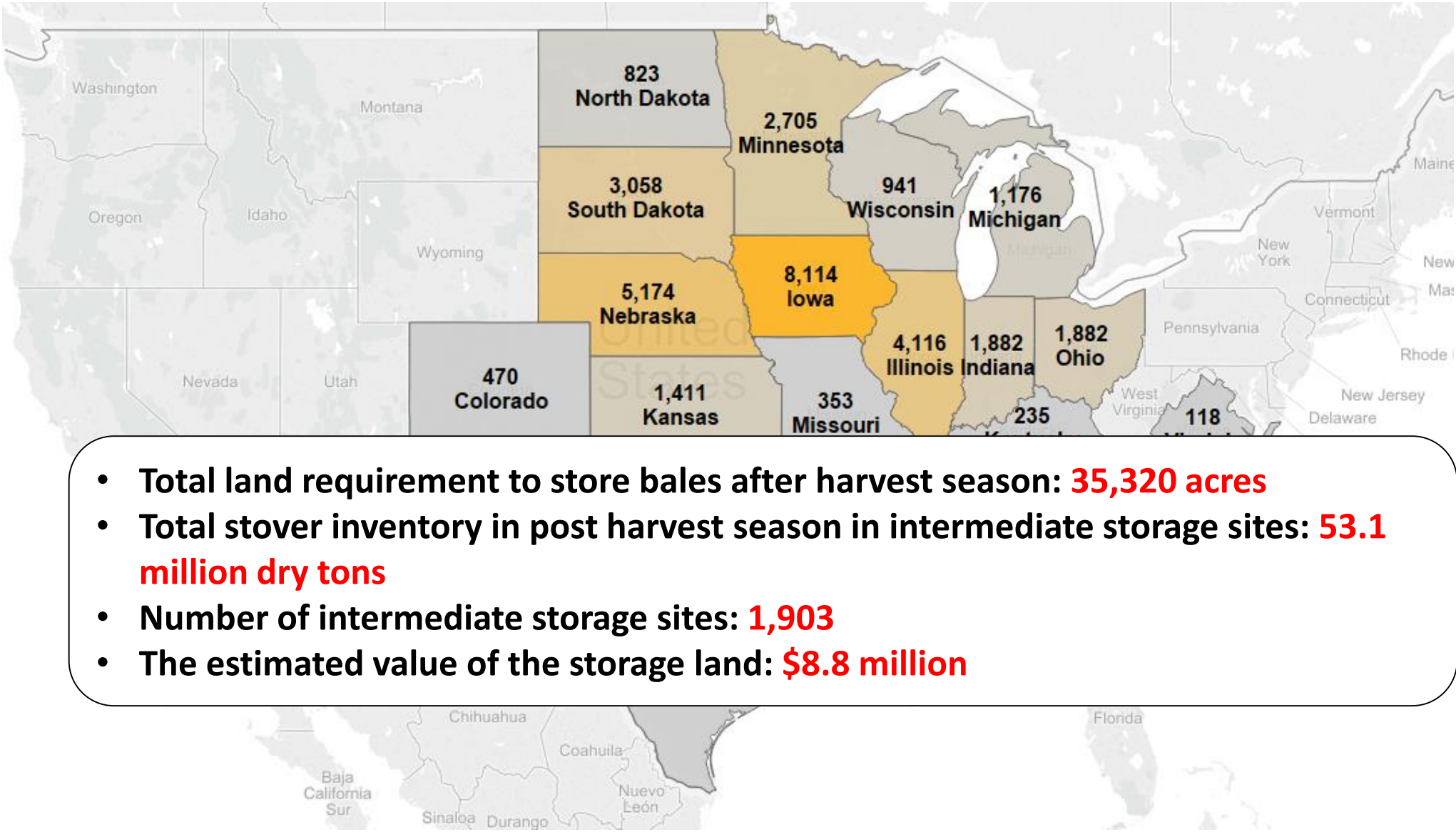
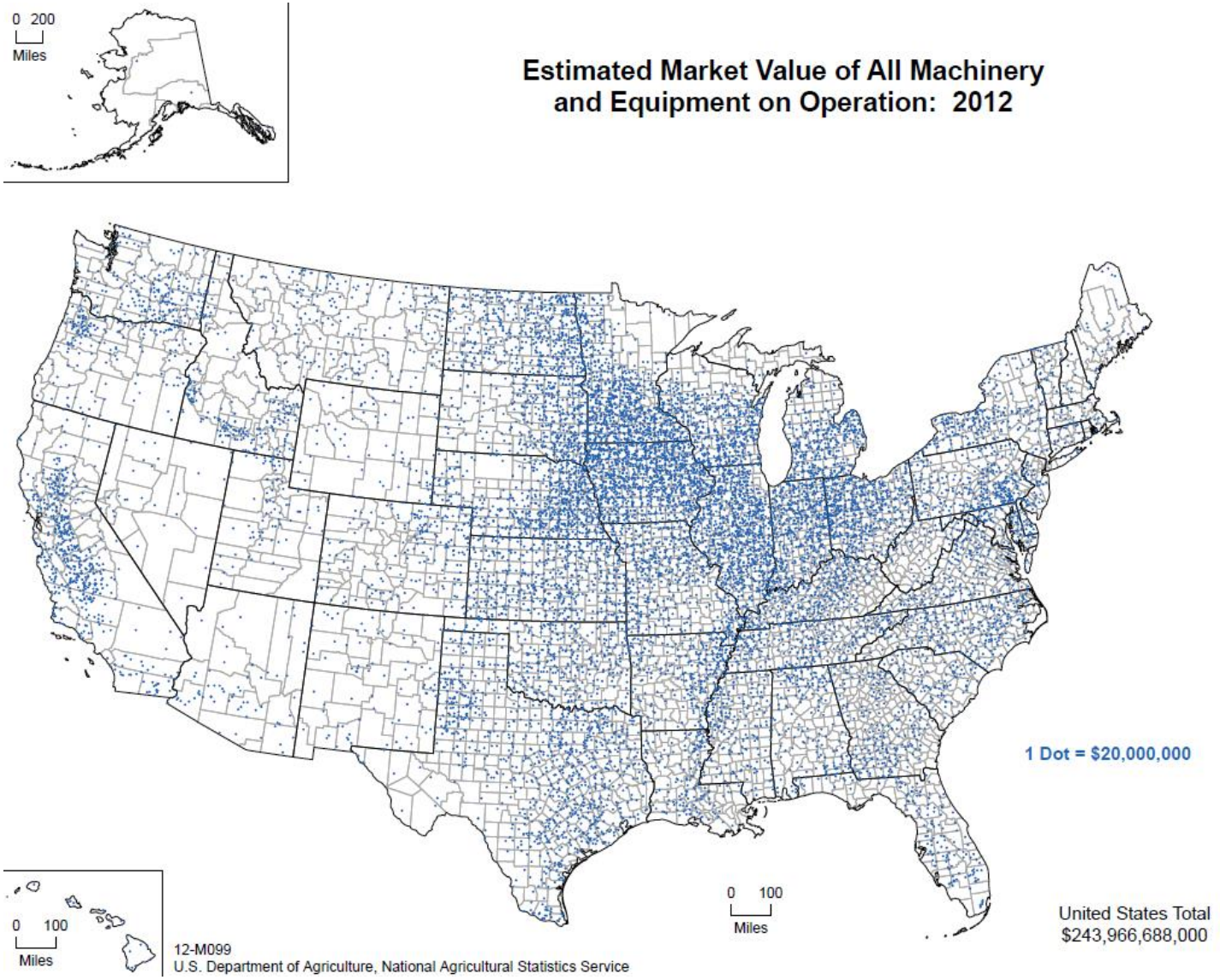


- **Total land requirement to store bales after harvest season: 35,320 acres**
- **Total stover inventory in post harvest season in intermediate storage sites: 53.1 million dry tons**
- **Number of intermediate storage sites: 1,903**
- **The estimated value of the storage land: $8.8 million**

Exiting agricultural equipment fleet in the USA



Sources: USDA, 2014.

Exiting agricultural equipment fleet in the USA

Equipment Type	
100+hp tractor	1.1 million units, 0.2 million units manufactured in the period of 2008-2012 and the rest prior to 2008.
Hay baler (small round and square balers)	over 0.7 million units. About 0.08 million units manufactured in the period of 2008-2012 and the rest prior to 2008.
Large square balers	1,600 units
truck fleet	3.3 million units. Over 0.5 units manufactured in the period of 2008-2012 and the rest prior to 2008.

Sources: USDA, 2014; Farris, 2015.

Conclusions

- **The obtained results demonstrate the economic and social significance of the corn stover bioeconomy in rural areas in the USA**

- **There is a profound potential for logistics equipment manufacturers to create jobs and wealth by increasing their production capacity**

- **The magnitude of the required logistics resources could be a limiting factor in short and mid-term for the sustainable development of the bioeconomy in the USA**

- **The existing fleet of field equipment can meet a portion of the equipment demand created by the biorefineries and their suppliers. The use of the existing equipment fleet depends on their age, efficiency, and availability in the supply region, the introduction of new technology or major changes in the equipment design and the supply chain models of the biorefineries and their suppliers (e.g. ownership, leased or rental).**

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