2015 International Workshop on Environment and Alternative Energy

Climate Change and Hydraulic Fracturing Proppants:

Calculating the Carbon Dioxide Equivalent Emissions from Silica Sand Production in Wisconsin

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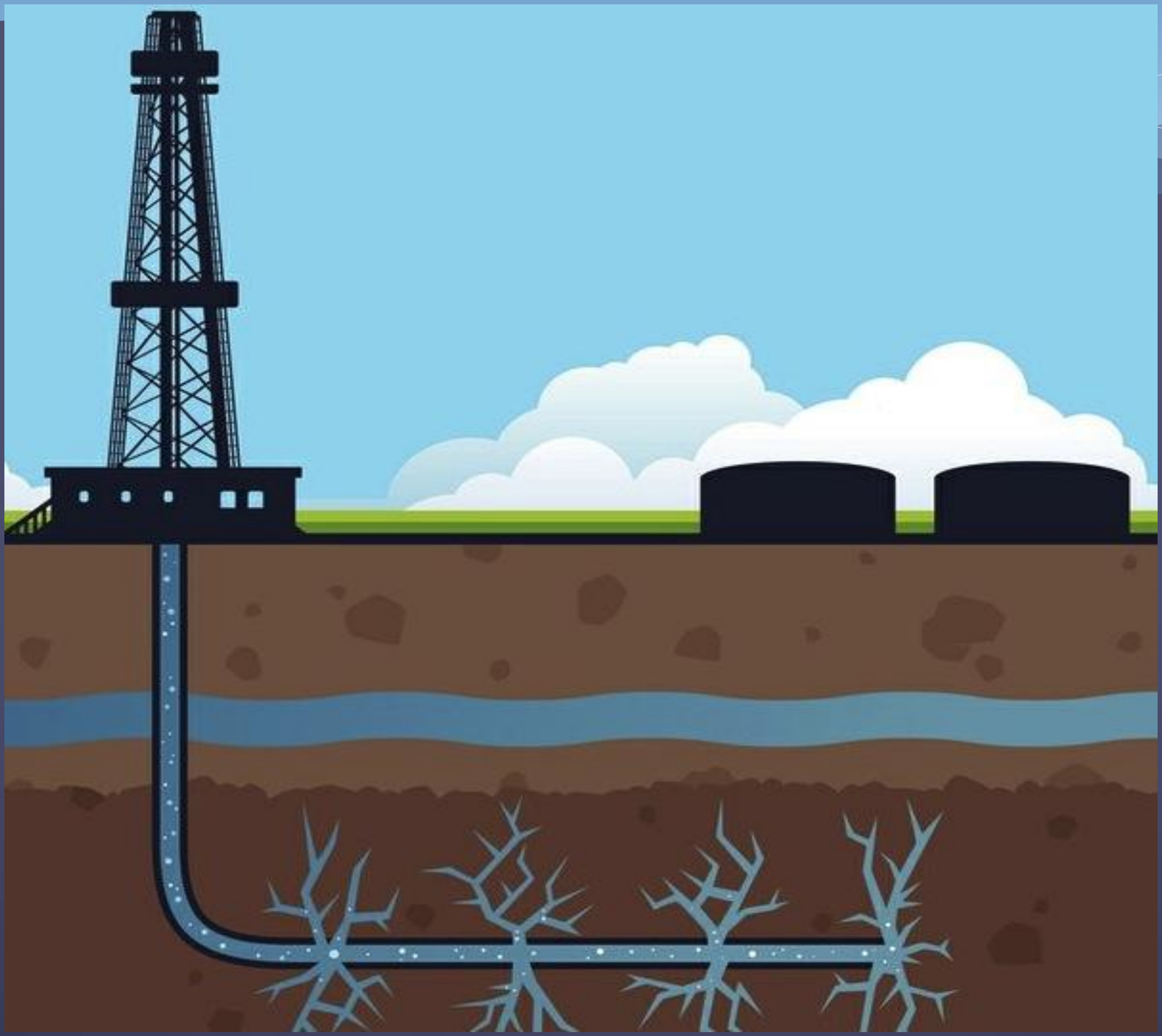
Purpose

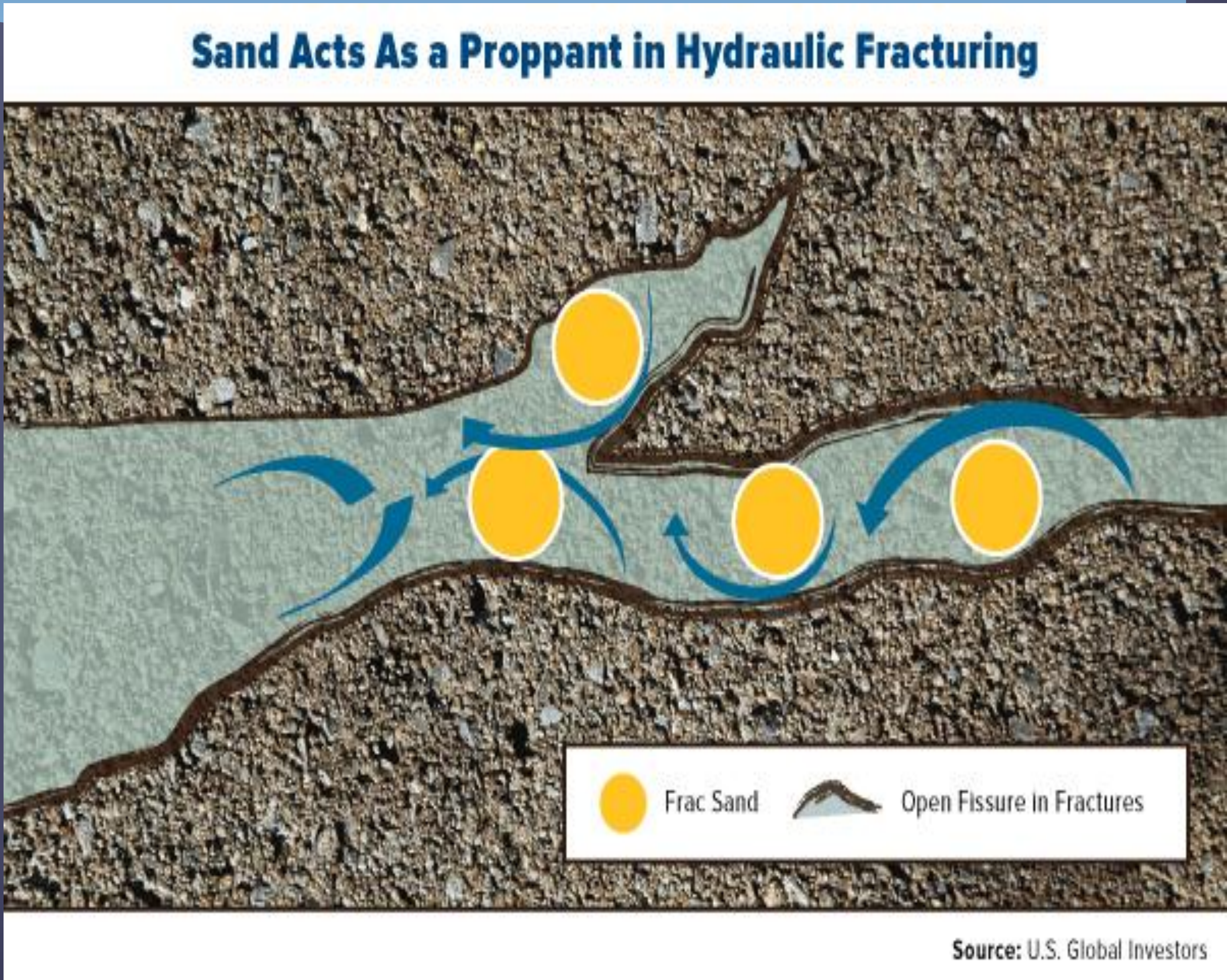
- Examine relationship between hydraulic fracturing and climate change
  - Calculate numerical quantity of greenhouse gas emissions released in life-cycle of hydraulic fracturing proppant

What is Hydraulic Fracturing?



Proppants = Propping Agents

Thousands of tons of proppants are needed for each hydraulic fracturing well

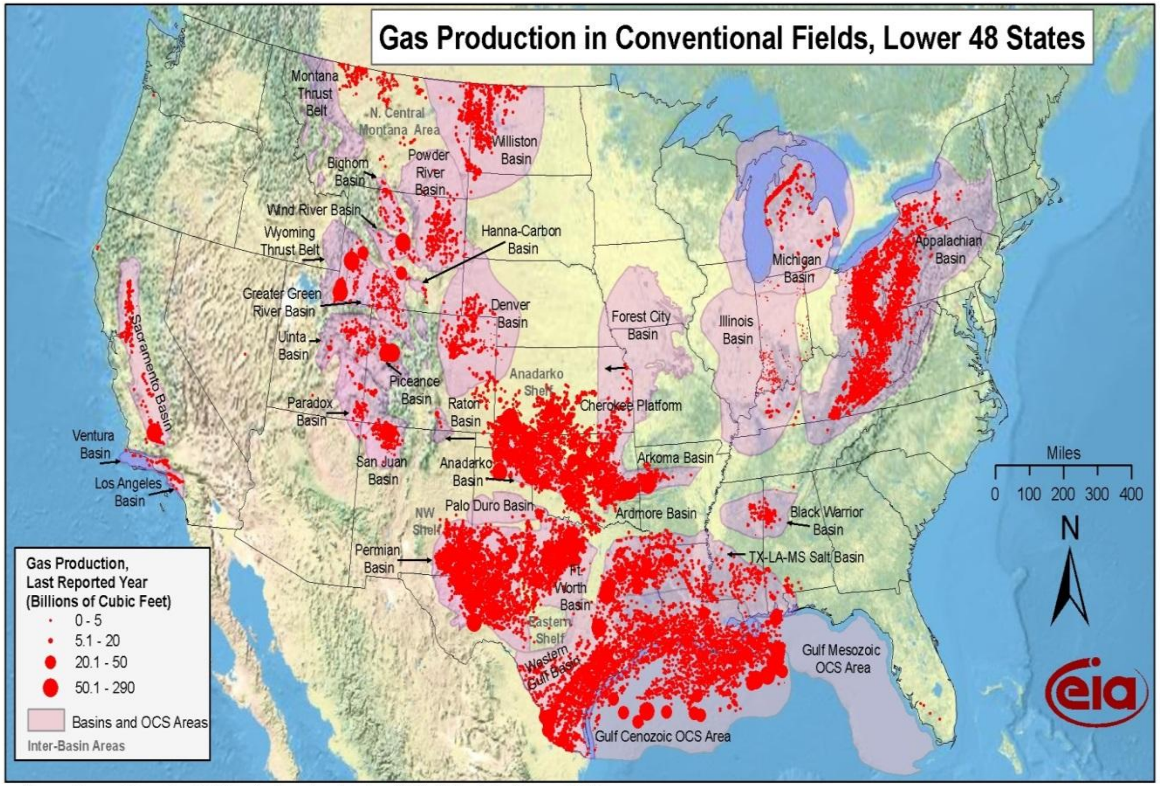


Silica Sand

- SiO_2
- 99% of all proppants
- 0.4 - 0.8 mm
- ~ 5,000 psi

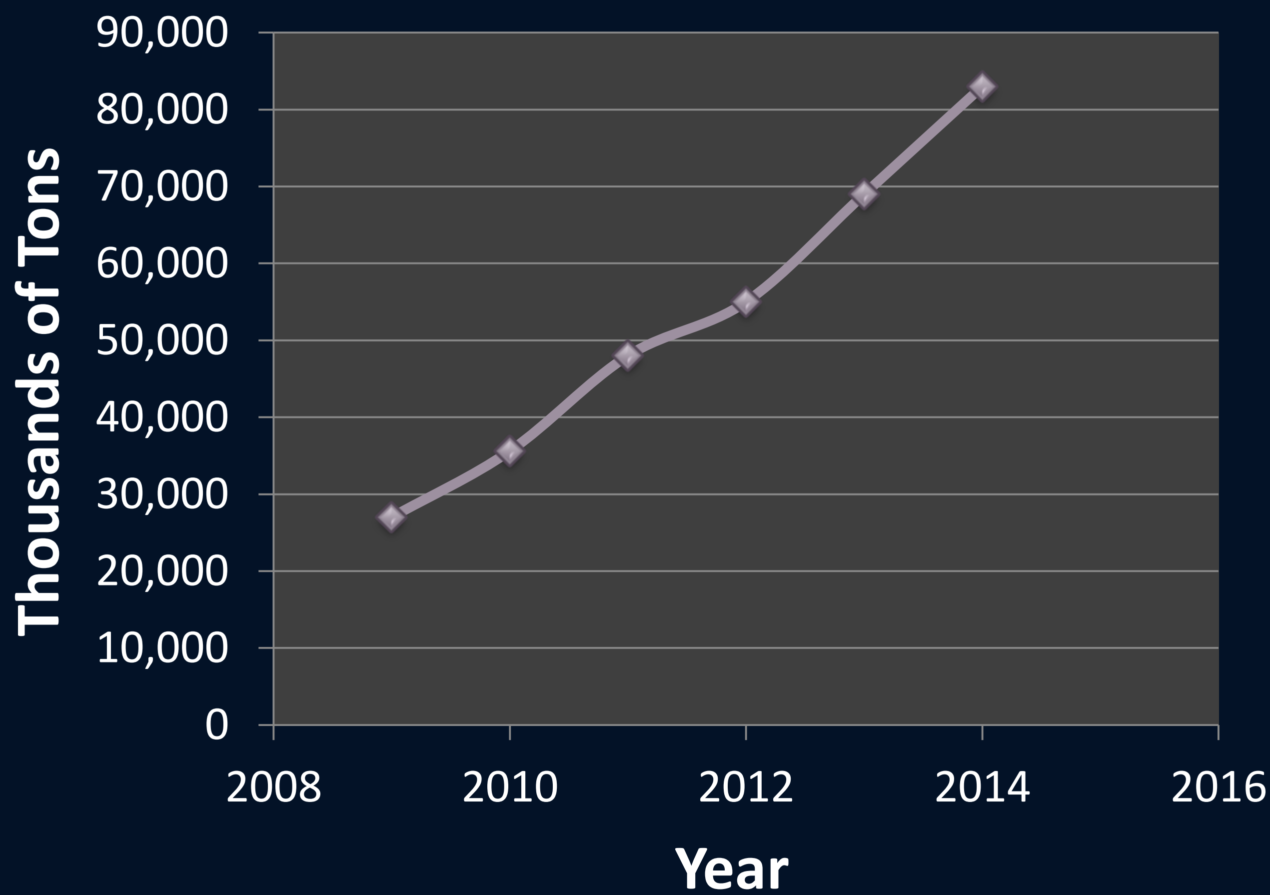
Hydraulic Fracturing Boom

- Currently 40% of all domestic oil and natural gas extraction
  - 75% by 2035
- 1.7 million active wells across the U.S.



Source: Energy Information Administration based on data from HPDI, IN Geological Survey, USGS

Silica Sand Boom



Nationwide Production of Silica Sand

USGS, 2015

Literature Review

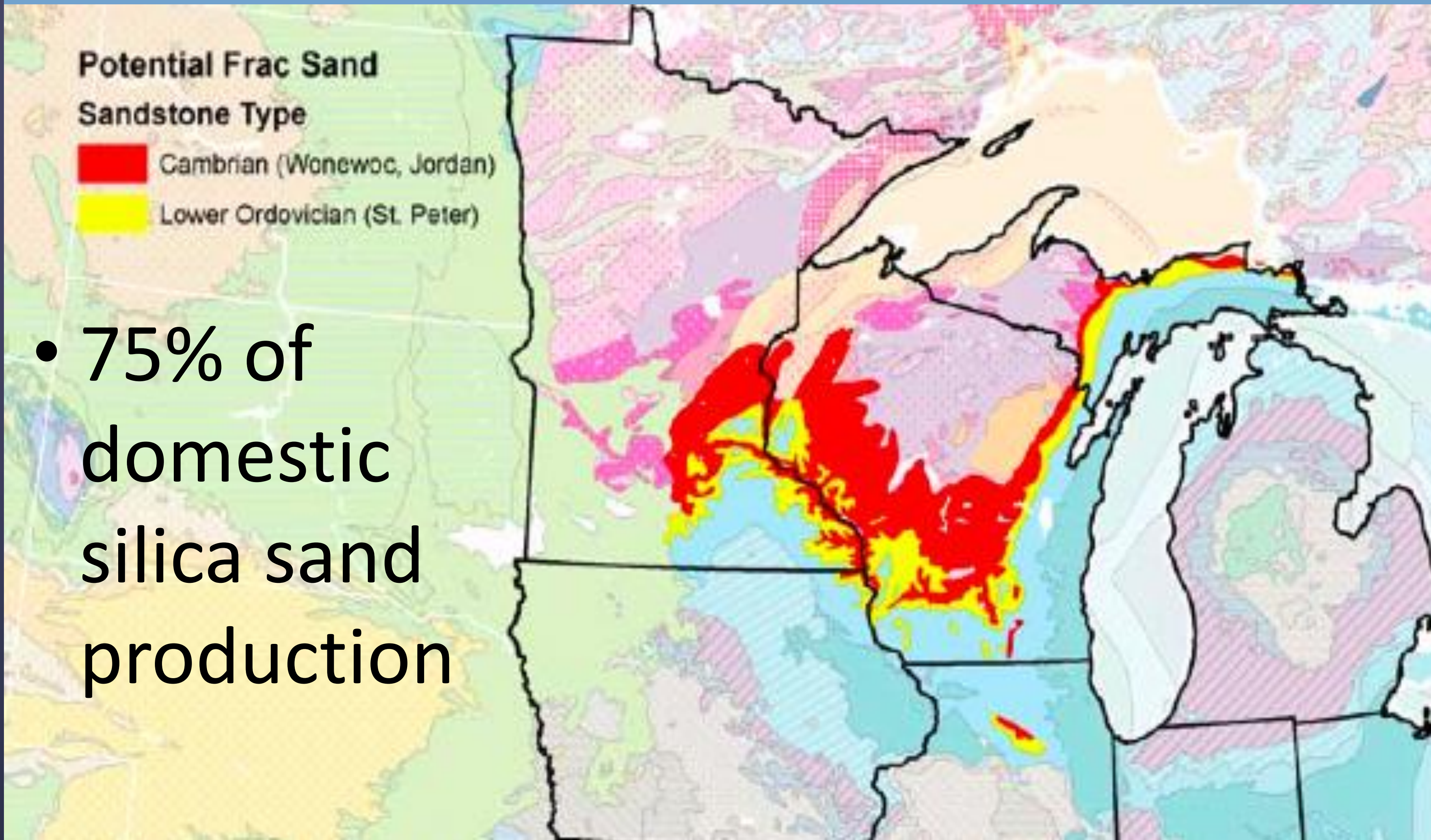
- Numerous life-cycle assessments of hydraulic fracturing have calculated greenhouse gas emissions
  - NONE included emissions from proppant production
- Other impacts of silica sand production have been documented but not emissions

Why is this important?

Research Questions

1. What quantity of CO_2e emissions is released from the production and distribution of silica sand proppant?
2. How do these emissions compare to life-cycle CO_2e emissions of hydraulic fracturing?
3. Should proppant production be included in future CO_2e life cycle analyses of hydraulic fracturing?

Wisconsin as a Case Study



- 75% of domestic silica sand production

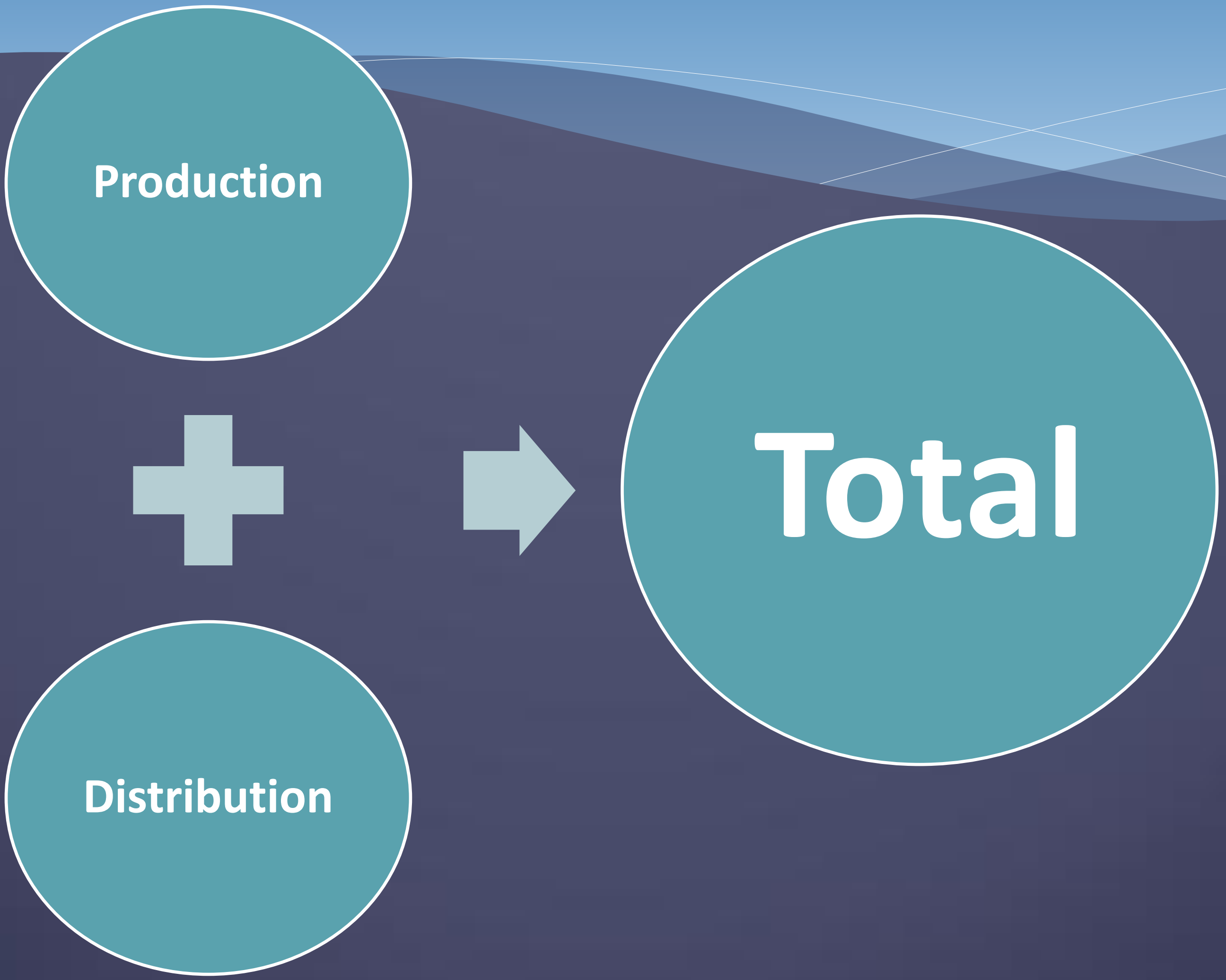
Silica Sand Production Process

Mining → Processing → Transportation

Production (Mining, Processing)

Distribution (Transportation)

Calculating CO_2e Emissions

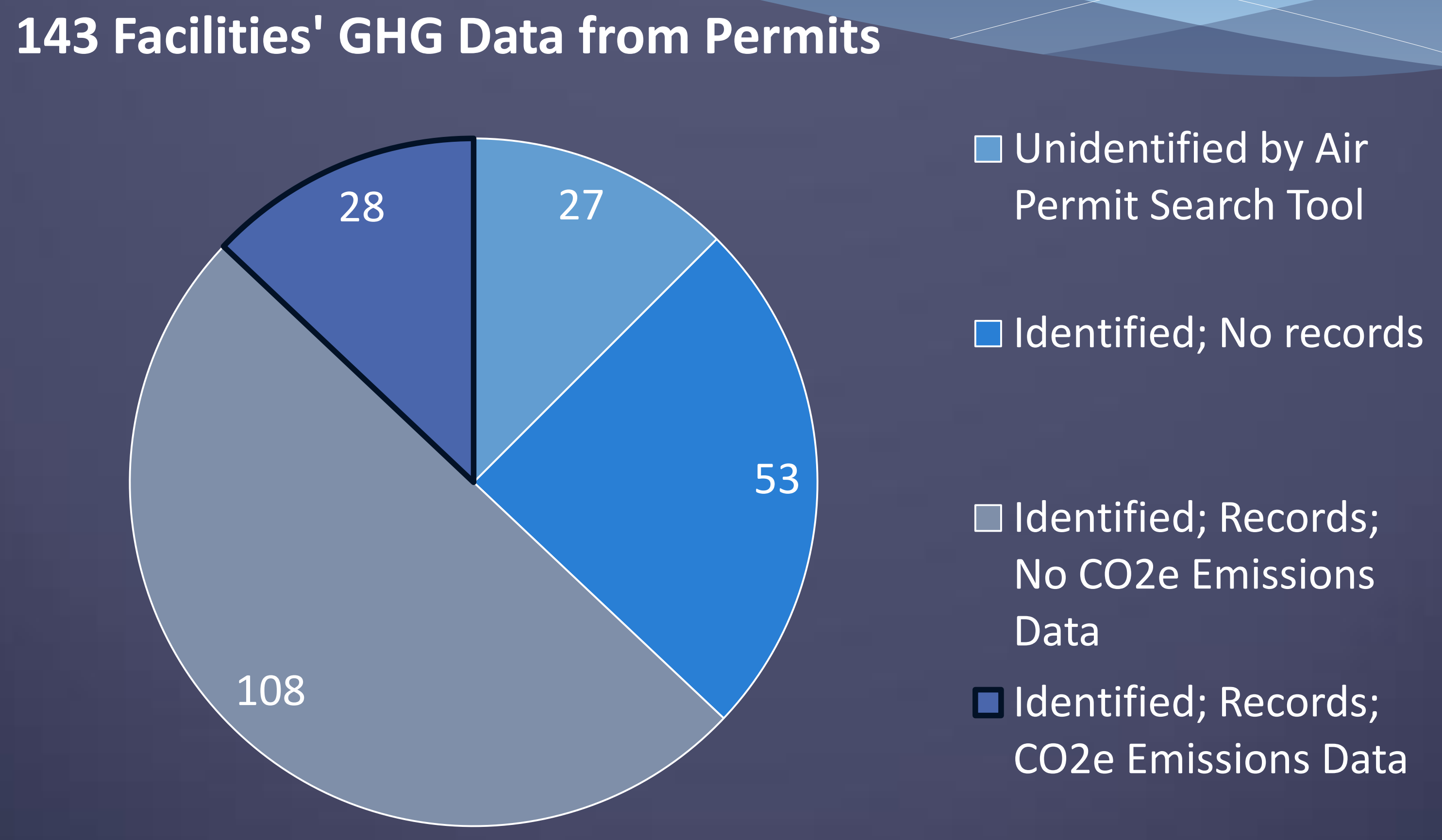


I. CO_2e Emissions from Production*

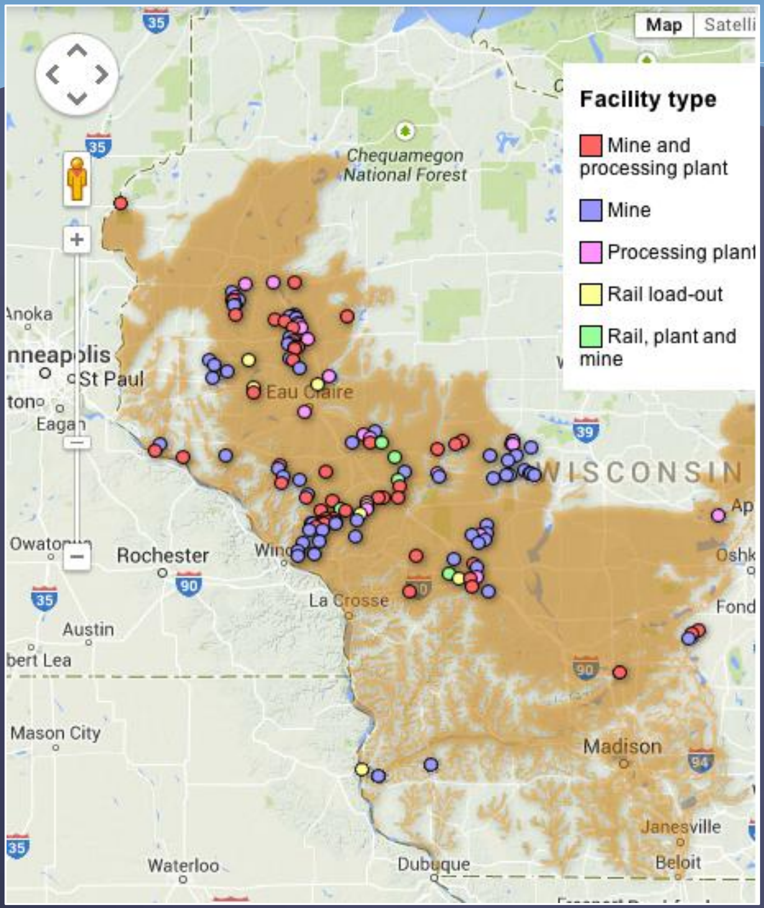
i. Examined 143 facility permits for CO_2e emissions data

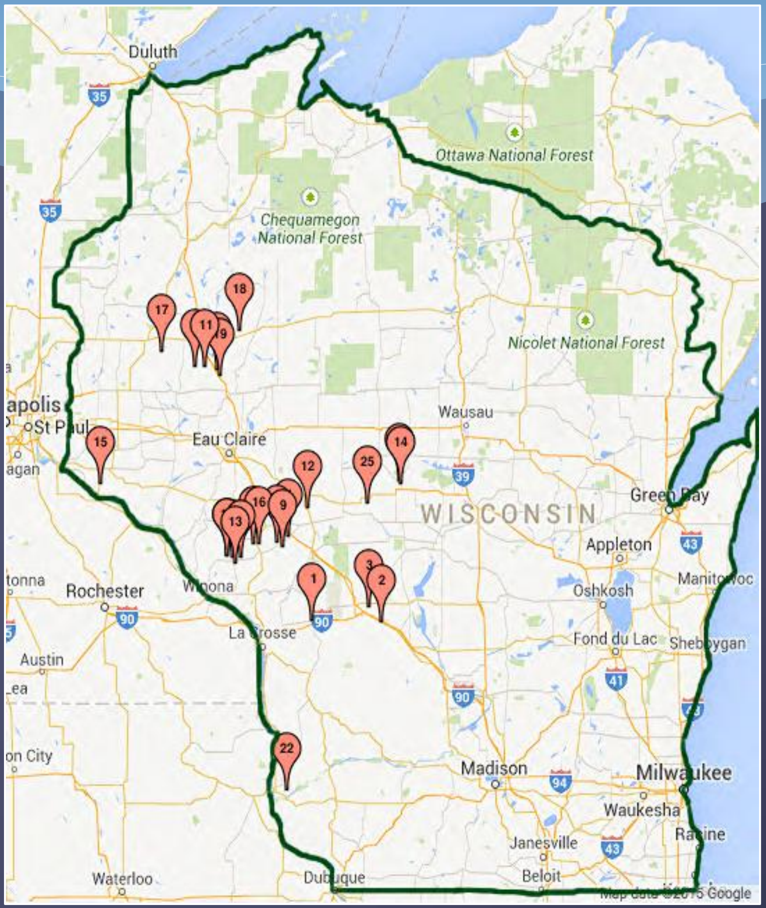
*Production was defined as the emissions from the mining, processing, and load out facilities involved in silica sand production.

I. CO_2e Emissions from Production



I. CO_2e Emissions from Production





Out of 143 active mining, processing, and load out facilities…

Only 28 provided CO_2e data in their permits

I. CO_2e Emissions from Production

i. Examined 143 facility permits for CO_2e emissions data

ii. Noted missing data in permits

2.2.6 Plant-wide Potential Emissions Summary

Table 2-18 Plant-wide Potential Emissions Summary

	Potential to Emit (PTE) Emissions																											
	PM		PM_{10}		$PM_{2.5}$		CO		CO_2		Lead		NO_x		N_2O		SO_2		TOC		Methane		VOC		GHG	
Sources:	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr
Truck Traffic	29.15	127.66	7.43	32.54	0.74	3.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stockpiles																										
Wet Plant Feed	0.22	0.96	0.11	0.48	0.02	0.07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mine Non Spec Sand	0.00	0.00	0.00	0.00	0.00	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dry Plant Feed(WP)	0.22	0.96	0.11	0.48	0.02	0.07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dry Plant Feed (DP)	0.22	0.96	0.11	0.48	0.02	0.07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dry Plant Non Spec (pre)	0.07	0.32	0.04	0.16	0.01	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dry Plant Non Spec (post)	0.07	0.32	0.04	0.16	0.01	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mine Pit Operations																										
Blasting	0.54	2.38	0.28	1.24	0.02	0.07	6.84	29.96	34.10	149.36	-	-	1.74	7.60	-	-	0.20	0.89	-	-	-	-	-	-	-	-
Drill	0.03	0.14	0.02	0.07	0.02	0.07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bulldozer - Crushing	1.97	8.63	1.48	6.47	0.21	0.91	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bulldozer - Overburden Shaping	1.97	8.63	1.48	6.47	0.21	0.91	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bulldozer - Non Spec Sand Placement	1.97	8.63	1.48	6.47	0.21	0.91	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Loader w/ Rock Breaker	0.18	0.36	0.08	0.16	0.02	0.03																				
Backhoe	0.12	0.30	0.06	0.15	0.02	0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mine End Front Loader	0.17	0.76	0.09	0.39	0.03	0.11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mine Pit Material Handling and Crushing	7.49	10.38	2.60	3.69	0.70	0.97	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dry Plant Fugitives	0.10	0.43	0.03	0.14	0.01	0.04																				
Dryer #1 (P20/C20/S20)	1.58	6.92	1.58	6.92	1.58	6.92	18.55	81.25	6235	27311	2.60E-05	1.14E-04	9.01	39.46	0.11	0.50	3.12E-02	0.14	0.57	2.50	0.12	0.52	0.29	1.25	6272	27473
Dry Plant (P30/C30/S30)	0.35	1.53	0.35	1.53	0.35	1.53	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Storage Operations (P40/C40/S30)	0.28	1.24	0.28	1.24	0.28	1.24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Loadout Spout (P50/C50/S30)	0.06	0.26	0.06	0.26	0.06	0.26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Facility Totals	46.77	181.78	17.70	69.51	4.50	17.53	25.39	111.21	6269.4	27459.9	2.60E-05	1.14E-04	10.75	47.07	0.11	0.50	0.24	1.03	0.57	2.50	0.12	0.52	0.29	1.25	6,272.35	27,472.88

* Discrepancies between the individual totals and the facility totals are due to rounding. The facility totals are the calculated PTE Emissions

I. CO_2e Emissions from Production

i. Examined 143 facility permits for CO_2e emissions data
ii. Noted missing data in permits
iii. Adjusted facility-reported data based on Northern Industrial Sands document

Northern Industrial Sands Document

BARR

Northern Industrial Sands – Fry Hill

Air Permit Application

Prepared for
Northern Industrial Sands – Fry Hill

June 2014

Table 2-1 Overburden Hauling and Reclamation Truck Traffic Assumptions

Overburden hauling/ reclamation	Value		Source
Haul Trucks	224	trucks/day	Based on maximum design capacity
Vehicle distance per round-trip	5,280	ft	Based on facility estimate
Empty haul truck weight	20	tons	
Weight transported per truck	22	tons	
Mean vehicle weight	31.0	tons	Based on 100% of the route carrying a full load
Trips	81,818	trip/yr	Based on weight transported per truck and year-round mine operation
Hourly Vehicle Rate	9.3	vehicles/hr	

- ‘Hourly Data’ – Hours of equipment usage (time)
- ‘Traffic Data’ – Distance traveled by vehicles on-site (miles)

Adjusting Facility-reported Data Based on Northern Industrial Sands Document

Equation 1: 'Hourly Data' CO_2 Emissions Calculation

$$\frac{hours\ of\ equipment\ use}{year}\ x\ \frac{equipment - specific\ grams\ CO_2\ release}{hour}\ x\ \frac{ton}{gram} = \frac{ton\ CO_2}{year}$$

Equation 2: 'Traffic Data' CO_2 Emissions Calculation

$$\frac{equipment\ trips}{year}\ x\ \frac{feet}{equipment\ trips}\ x\ \frac{mile}{feet}\ x\ \frac{gallons\ fuel\ used}{mile}\ x\ \frac{ton\ CO_2}{gallons\ fuel\ used} = \frac{ton\ CO_2}{year}$$

I. CO_2e Emissions from Production

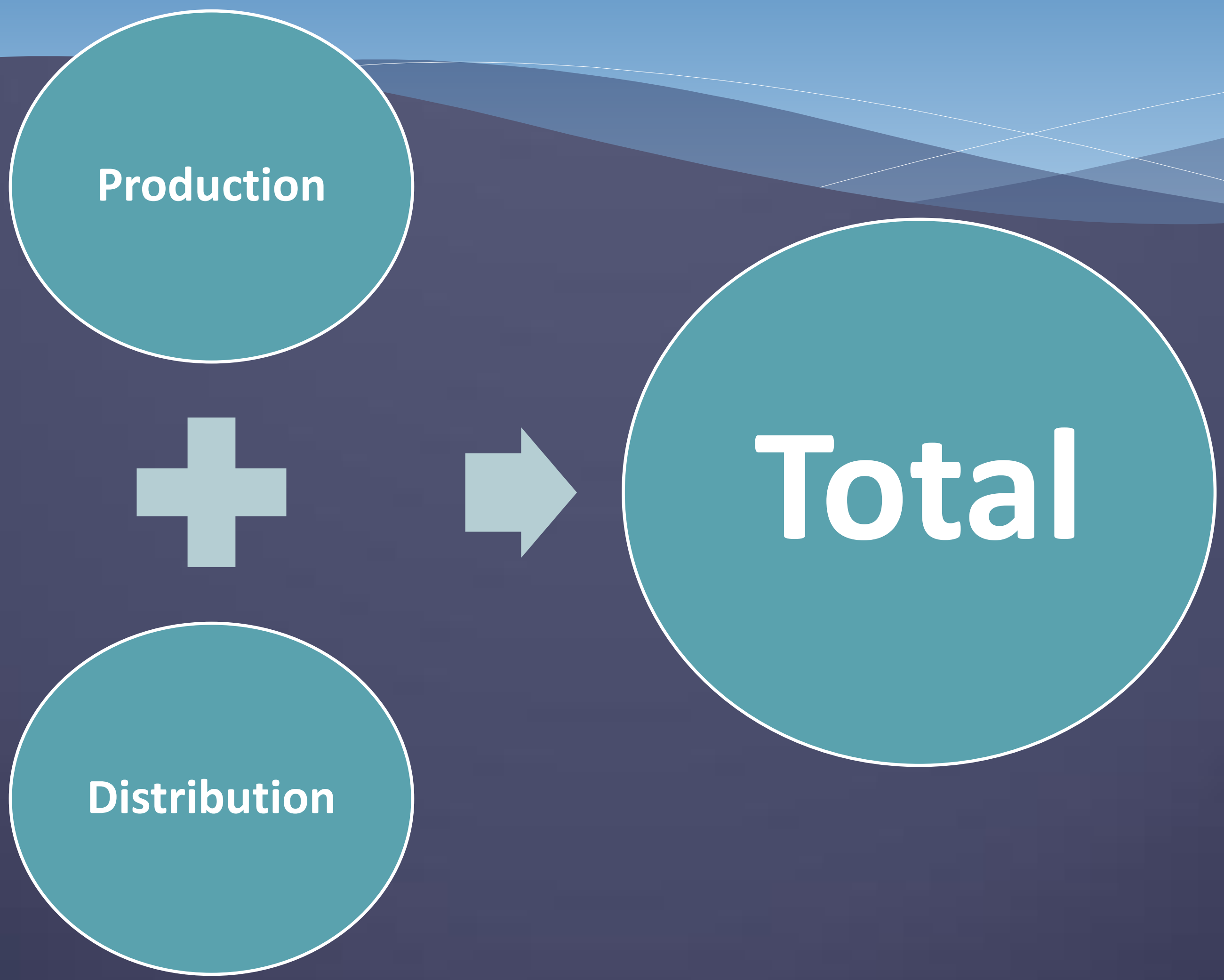
i. Examined 143 facility permits for CO_2e emissions data

ii. Noted missing data in permits

iii. Adjusted facility-reported data based on Northern Industrial Sands Document

iv. Obtained percent increase and extrapolated statewide

Calculating CO_2e Emissions



II. CO_2e Emissions from Distribution*

i. Used low and high estimates of silica sand outputs from Wisconsin to provide range

- 26 and 40 million tons

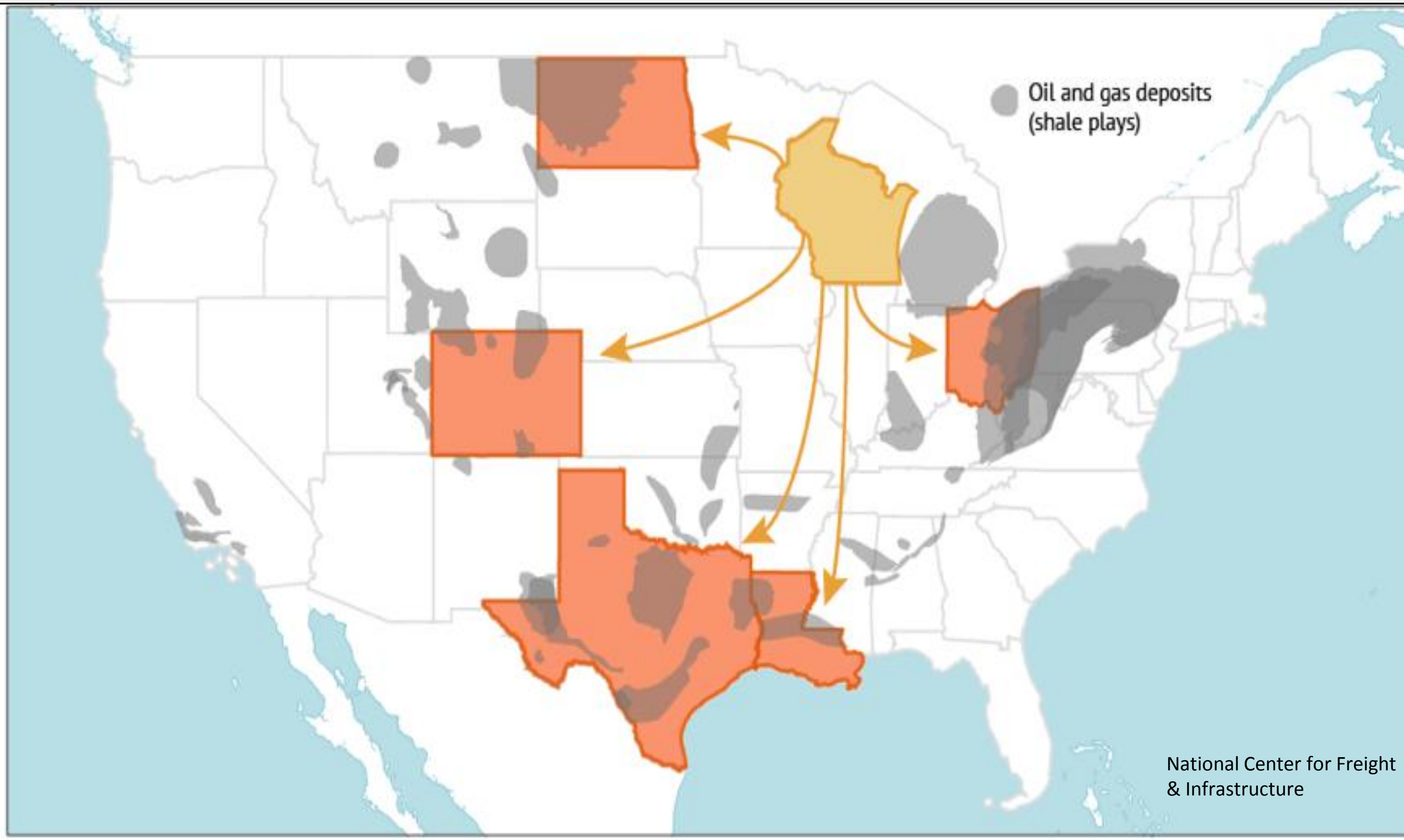
ii. Assumed equal distribution to top five states

- Texas, Louisiana, Colorado, North Dakota, Ohio

*Distribution was defined as the emissions from exporting silica sand output to hydraulic fracturing wells.

II. CO_2e Emissions from Distribution

Top 5 Destinations for Wisconsin Silica Sand



II. CO_2e Emissions from Distribution

i. Used high and low estimates of silica sand output from Wisconsin to provide range

- 26 and 40 million tons

ii. Assumed equal distribution to top five states

- Texas, Louisiana, Colorado, North Dakota, Ohio

iii. Calculated emissions using fuel efficiency rates of rail and truck transportation

- 30% truck, 70% rail

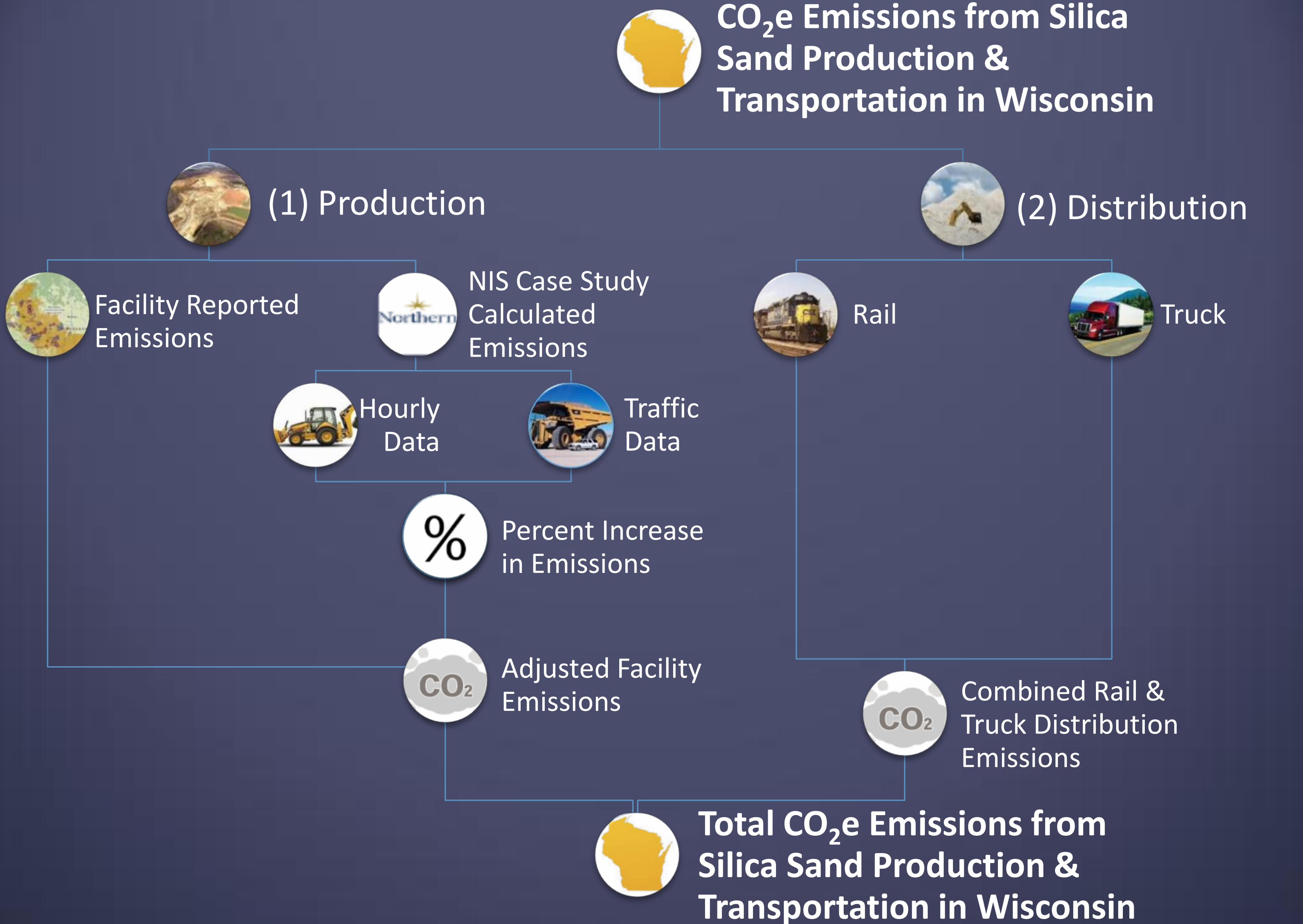
II. CO_2e Emissions from Distribution

Equation 3: Rail Transportation CO_2 Emissions Calculation

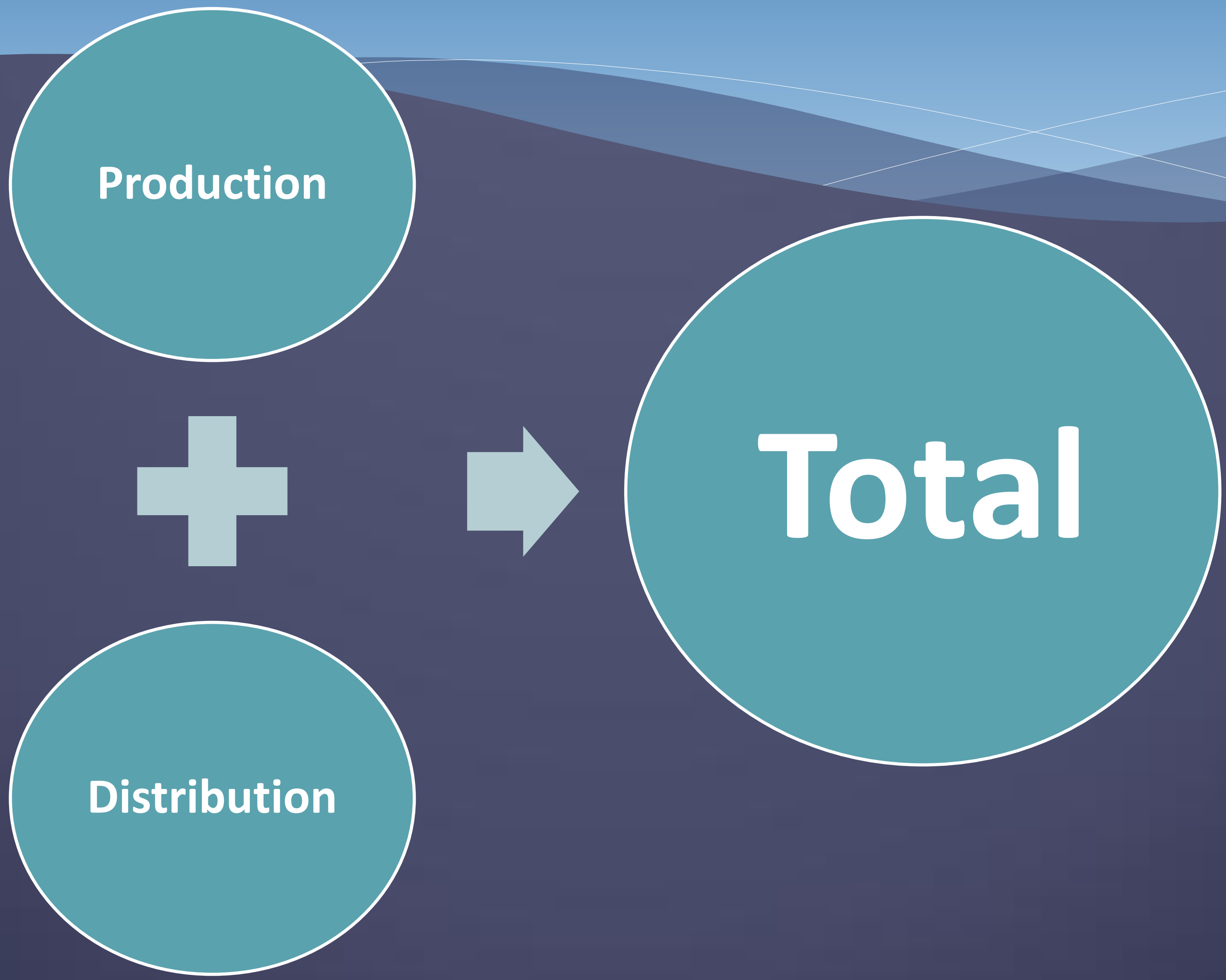
$$tons\ sand\ hauled\ x\ miles\ to\ destination\ x \frac{gallon\ diesel\ fuel}{ton\ miles}\ x \frac{ton\ CO_2}{gallon\ diesel\ fuel} = ton\ CO_2$$

Equation 4: Truck Transportation CO_2 Emissions Calculation

$$miles\ to\ destination\ x\ \frac{gallons\ diesel\ fuel}{mile}\ x \frac{ton\ CO_2}{mile} = ton\ CO_2$$


CO2e Emissions from Silica Sand Production & Transportation in Wisconsin
(1) Production
(2) Distribution
Facility Reported Emissions
Northern
NIS Case Study Calculated Emissions
Hourly Data
Traffic Data
Percent Increase in Emissions
CO2
Adjusted Facility Emissions
Rail
Truck
CO2
Combined Rail & Truck Distribution Emissions
Total CO2e Emissions from Silica Sand Production & Transportation in Wisconsin

Calculating CO_2e Emissions



III. Total CO_2e Emissions

i. Added Production and Distribution emissions data together (tonnage)
ii. Converted to emissions per ton silica sand
iii. Calculated ratio of solely proppant emissions to total hydraulic fracturing emissions

IOP Publishing — Environmental Research Letters
Environ. Res. Lett. 6 (2011) 034014 (9pp) — doi:10.1088/1748-9326/6/3/034014

Life cycle greenhouse gas emissions of Marcellus shale gas

Department of Energy & Climate Change

Potential Greenhouse Gas Emissions Associated with Shale Gas Extraction and Use

Professor David J C MacKay FRS

Dr Timothy J Stone CBE

9th September 2013

Shale Gas Production: Potential versus Actual GHG Emissions

Francis O'Sullivan and Sergey Paltsev

MIT Joint Program on the Science and Policy of Global Change

Results

Answering the Research Questions

1. How much CO_2e emissions are released from the production and distribution of silica sand proppant?

- **Emissions from Production:** ~3.3 million TPY

Production: CO_2e Emissions from Wisconsin Facilities	
Lower Estimate (CO_2e TPY)	3,247,452
Upper Estimate (CO_2e TPY)	3,432,910

Summary of Calculated CO_2 Emissions Data and NIS Provided Data (TPY)

Facility-Reported Data		Calculated Estimate	
	Blasting	149	
	Sand Dryer	27,311	
Total		27,460	
Calculated Emissions Data		Lower Estimate	Upper Estimate
Calculated Hourly Data Totals		345	494
Calculated Traffic Data Totals		1074	2510
Total Additional Emissions		1419	3004
Total Estimated Emissions (Facility-Reported + Calculated)		28,880	30,465
Percent of Total Emissions Added		5%	11%

Answering the Research Questions

1. How much CO_2e emissions are released from the production and distribution of silica sand proppant?

- **Emissions from Production:** ~3.3 million TPY
  - Facility emissions: 5% - 11% higher than reported
  - Adjusted Facility Average: 34,000 tons CO_2e emissions per year

Adjusted CO_2e Facility Emissions (TPY)

Facility No.	FID	Reported CO2e Emissions	Adjusted Low Estimate (5% increase)	Adjusted High Estimate (11% increase)
1	662029940	28,597	30,027	31,742
2	627007260	62,102	65,207	68,933
3	662030380	1,585	1,664	1,759
4	772151270	9,800	10,290	10,878
5	603107010	44,000	46,200	48,840
6	610078590	30,000	31,500	33,300
7	609128960	38,894	40,839	43,172
8	772145770	18,922	19,868	21,003
9	662031150	11,019	11,570	12,231
10	603106680	70,996	74,545	78,806
11	662067560	60,733	63,770	67,414
12	662068110	1,379	1,448	1,531
13	662069540	715	751	794
14	610079140	636	668	706
15	662031040	21,034	22,086	23,348
16	603111190	27,473	28,847	30,495
17	612018550	55	58	61
18	662028620	18,566	19,494	20,608
19	662070090	28,672	30,106	31,826
20	729038640	24,449	25,672	27,138
21	603111410	28,620	30,051	31,768
22	627023210	57,158	60,016	63,445
23	855010310	46, 121	48,427	51,194
24	603110860	57,967	60,865	64,343
25	627021670	12,083	12,687	13,412
26	642078800	45,862	48,155	50,907
27	648017920	121,600	127,680	134,976
28	642028420	21,880	22,974	24,287
Facility Average			**33,410**	**35,318**

Answering the Research Questions

1. How much CO_2e emissions are released from the production and distribution of silica sand proppant?

- **Emissions from Production:** ~3.3 million TPY
  - Facility emissions: 5% - 11% higher than reported
  - Adjusted Facility Average: 34,000 tons CO_2e emissions per year
- **Emissions from Distribution:** ~1.2 million TPY

Distribution: CO_2e Emissions from Rail and Truck Transportation	
Lower Estimate (CO_2e TPY)	936,356
Upper Estimate (CO_2e TPY)	1,440,349

Answering the Research Questions

1. How much CO_2e emissions are released from the production and distribution of silica sand proppant?

- **Emissions from Production:** ~3.3 million TPY
  - Facility emissions: 5% - 11% higher than reported
  - Adjusted Facility Average: 34,000 tons CO_2e emissions per year
- **Emissions from Distribution:** ~1.2 million TPY
- **Total:** ~4.5 million TPY

Total: Silica Sand Proppant Production and Distribution CO_2e Emissions in Wisconsin		
	Lower Estimate (TPY)	Upper Estimate (TPY)
Production	3,247,452	3,432,910
Distribution	936,356	1,440,349
Total	**4,183,808**	**4,873,259**

Equivalent to annual greenhouse gas emissions from 860,000 passenger vehicles

Answering the Research Questions

2. How do these emissions compare to life cycle CO_2e emissions of hydraulic fracturing?

- 0.15 ton CO_2e per ton silica sand produced
- 5-34% increase in emissions if LCAs of hydraulic fracturing included proppant production

Summary of Percent Increase in Overall Hydraulic Fracturing Emissions due to Silica Sand Production

Authors	Scope	Finding (t CO_2e per well)	Percent Increase in Emissions of Silica Sand Production	
			Lower Estimate	Upper Estimate
O'Sullivan & Paltsev (2011)	Least extensive; only emissions during natural gas production; CH_4 emissions only	1,378	19%	34%
Griffith et al. (2011)	Extensive; well development to completion; specific to Marcellus Shale	5,500	15%	27%
MacKay & Stone (2013)	Most extensive; well development to completion and additional elements	4,887	5%	10%

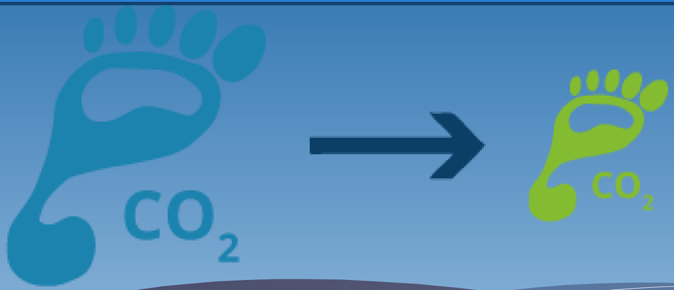
Answering the Research Questions

3. Should proppant production be included in future life cycle analyses of CO_2e calculations of hydraulic fracturing?

Yes!

Conclusions

- Tremendous need for facility greenhouse gas data
- Proppant production emissions absent from hydraulic fracturing GHG research
- A 5-34% increase in life cycle assessment calculations of hydraulic fracturing is extremely significant for policy-makers, scientists, and the public



Recommendations for Emissions Reduction

- Reduce distance between mine site and processing site
- Upgrade equipment efficiency
- Switch transportation method from truck to rail (3x more efficient)
- Recover and re-use proppants
- Regulate facility emissions with a long-term system of greenhouse gas monitoring

Future Research

- Replace assumptions with hard data
- Reach beyond the scope of Wisconsin
- Examine the feasibility and efficiency of proppant recovery and recycling after use.

Acknowledgements

esa

European Space Agency

NASA

UCSB

Image Sources

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Thank you!

Questions?