An Attempt to Develop a Bottom-up Methodology for Estimating Methane Emissions from Surface Coal Mines in India

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Introduction

Estimates of methane emissions from surface mines are based on generic emission factors for most countries (except Australia), yet satellite imagery shows there is great variability in surface mine emissions. There is a need for more precise investigation of methane emission from surface mine, especially where surface mines account for most of production (the case for India).

Central Mine Planning and Design Institute (CMPDI) systematically collects core hole data from exploratory coal blocks (mines) in India. As part of the process, CMPDI drills two core holes per exploration block to collect stratigraphic data (depth and thickness) of the seams, as well as gas content data. This project is investigating using data from these core holes to develop more accurate/precise methane emissions estimates for surface coal mines.

This presentation reviews available data, discusses the opportunities the data presents as well as its limitation, in the context of Australia's and U.S.'s methodologies for estimating methane emissions from surface coal mines.

The proposed approach relies on the following data, provided by CMPDI:

- Mine Plan for Manikpur block/mine
- Coal Production (April 2021- Mar 2022)
- Lithologs
- Gas Content Data (neighboring blocks of Mandraigarh and Korba)

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Potential Methodology Considerations

As per IPCC approach, to estimate emissions of methane from open coal mines, it is necessary to consider methane emissions from:

1) Removed overburden/ interburden
2) Mines seams
3) Underbuden (as disturbed strata below would continue to release methane)

The option the team considered to estimate emissions from these coal seams is to use seam-specific data from coal core samples to find block/mine-specific emission factors multiplied by detailed production data (tonnage).

The following slides detail the steps involved in constructing the table for the Manikpur coal mine below. From 2021 to 2022, mined tonnage at the Manikpur mine 4.9 million tonnes of coal.

Mined Seam						
Seam	**Thickness (m)**	**Depth (m)**	**Gas Content (M^3/tonne)**	**Percent of Total Tonnage**	**Tonnage**	**Emissions (million M^3)**
XX	5	50	0.41	0.08	0.41	0.17
XIX	13	100	1.11	0.22	1.08	1.20
XVIII	42	150	1.75	0.7	3.43	6.00
Totals	**60**			**1.00**	**4.92**	**7.37**

Overburden/Interburden						
Seam	**Thickness (m)**	**Depth (m)**	**Gas Content (M^3/tonne)**	**Percent of Total Tonnage**	**Tonnage**	**Emissions (million M^3)**
	1.36	125	1.45			
Totals	**1.36**		**1.45**		**0.11**	**0.16**

Underburden						
Seam	**Thickness (m)**	**Depth (m)**	**Gas Content (M3/tonne)**	**Percent of Total Tonnage**	**Tonnage**	**Emissions (million M3)**
	5	180	2		0.41	0.82
Totals	**5**	**180**	**2**		**0.41**	**0.82**

Total Emissions	8.35	Million M^3

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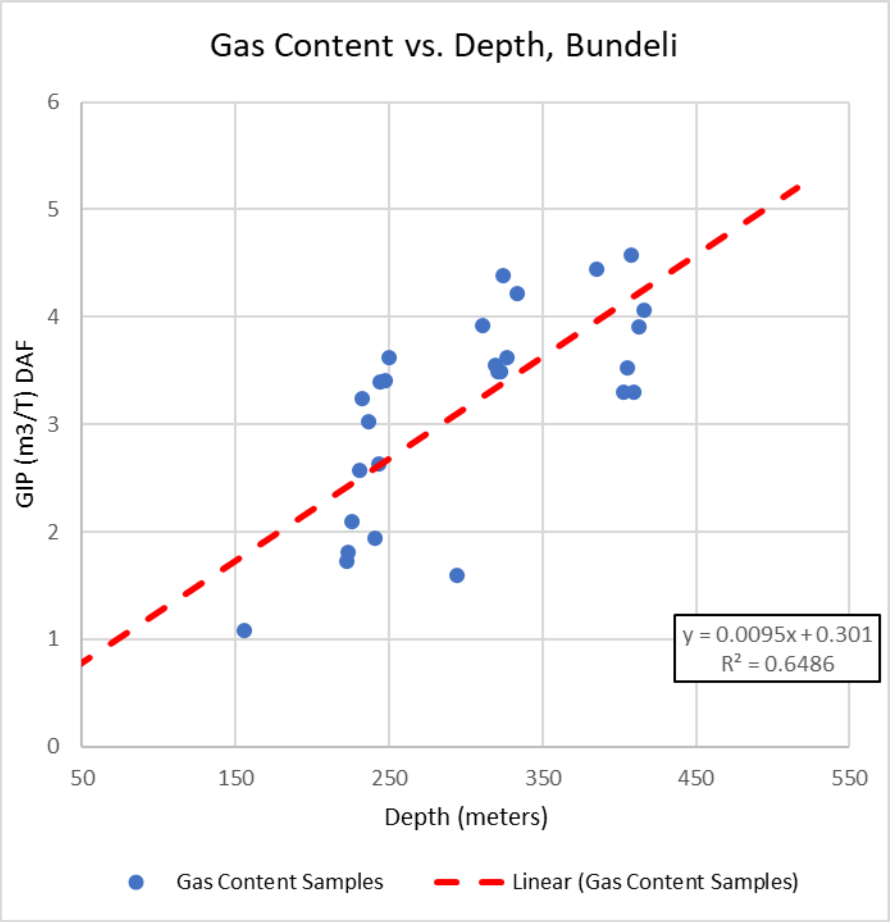
Step 1: Develop Gas Content Estimates



- Using the gas content data acquired by CMPDI, a gas content versus depth curve was constructed for the coal block.

Step 2: Calculate Coal Tonnages

Part 1: Emissions Calculations for Mined Seam(s)

- For mines that are mining a single seam, the tonnage will equal the reported tonnage mined.
- In the case of multiple mined seams (as is the case for the Manikpur mine), the tonnage of individual mined seams will be used.
- In the case of the Manikpur mine, the tonnage of individual seams (at depths 50m to 150m) was calculated based on their weighted average of the total coal thickness mined multiplied by the total tonnage mined as shown in the table below.

Mined Seam						
Seam	Thickness (m)	Depth (m)	Gas Content (M^3/tonne)	Percent of Total Tonnage	Tonnage	Emissions (million M^3)
XX	5	50	0.41	0.08	0.41	0.17
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Step 2: Calculate Coal Tonnages

Part 2: Emissions Calculations for Overburden/Interburden

- The emissions for coal seams in the overburden/interburden are calculated in a similar manner to the mined seam(s).
- In the case of the Manikpur mine, there are no seams above the shallowest mine seam, the XX seam, so there is no contribution of methane from the overburden.
  - However, there is a seam in between the XX and XIX seam. Its tonnage was multiplied by the estimated gas content to determine the emissions as shown in the table below.

Overburden/Interburden						
Seam	Thickness (m)	Depth (m)	Gas Content (M^3/tonne)	Percent of Total Tonnage	Tonnage	Emissions (million M^3)
	1.36	125	1.45			
Totals	**1.36**		**1.45**		**0.11**	**0.16**

Step 2: Calculate Coal Tonnages

Part 3: Emissions Calculations for Underburden

After the removal of the overburden and the mined seam(s), a zone of relaxation is created below the mined seam.

- This zone of relaxation creates fractures which can allow methane to migrate from underlying seams to the pit floor, and in some cases these emissions can be significant (see the photo below).
- While the extent of the underlying zone of relaxation will vary based on the size of the mine area and the lithology of the strata, this zone generally extends between 30-50 m below the mined seam.

Methane flare from an opencast pit floor in Canada.

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Step 2: Calculate Coal Tonnages

Part 3 (cont.): Emissions Calculations for Underburden

- For underburden emissions, all seams within 30 m below the deepest mined seam were included in the total emissions estimate.
- The volume of methane emissions from the underburden was calculated by multiplying the tonnage by the estimated gas content as shown in the table below.
- Methane emissions from the underburden seams are expected to be released when the pressure is lowered, and fractures are created. Seepage will continue for years. In this methodology, we simplify the geological processes and assume that the underburden will liberate 100% of methane within 30 m of the floor of the lowest mined seam.

Underburden						
Seam	**Thickness (m)**	**Depth (m)**	**Gas Content (M^3/tonne)**	**Percent of Total Tonnage**	**Tonnage**	**Emissions (million M^3)**
	5	180	2		0.41	0.82
Totals	**5**	**180**	**2**		**0.41**	**0.82**

Overview of U.S. Methodology

- The U.S. methodology for estimating methane emissions from surface coal mines involves the use of an IPCC Tier 2 method (EPA, 2023).
  - For surface mines, **basin-specific coal production** obtained from the Energy Information Administration's Annual Coal Report (EIA, 2022) is multiplied by **basin-specific methane contents**, established through a study, and a **150 percent multiplier** is applied (to account for methane from over-burden and under-burden) to estimate methane emissions (EPA, 2023). Estimates are also disaggreaged to State-level.
  - Additional information involving the U.S. methodology can be found in the Environmental Protection Agency's (EPA) *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021*, which is available for download on the EPA's website.

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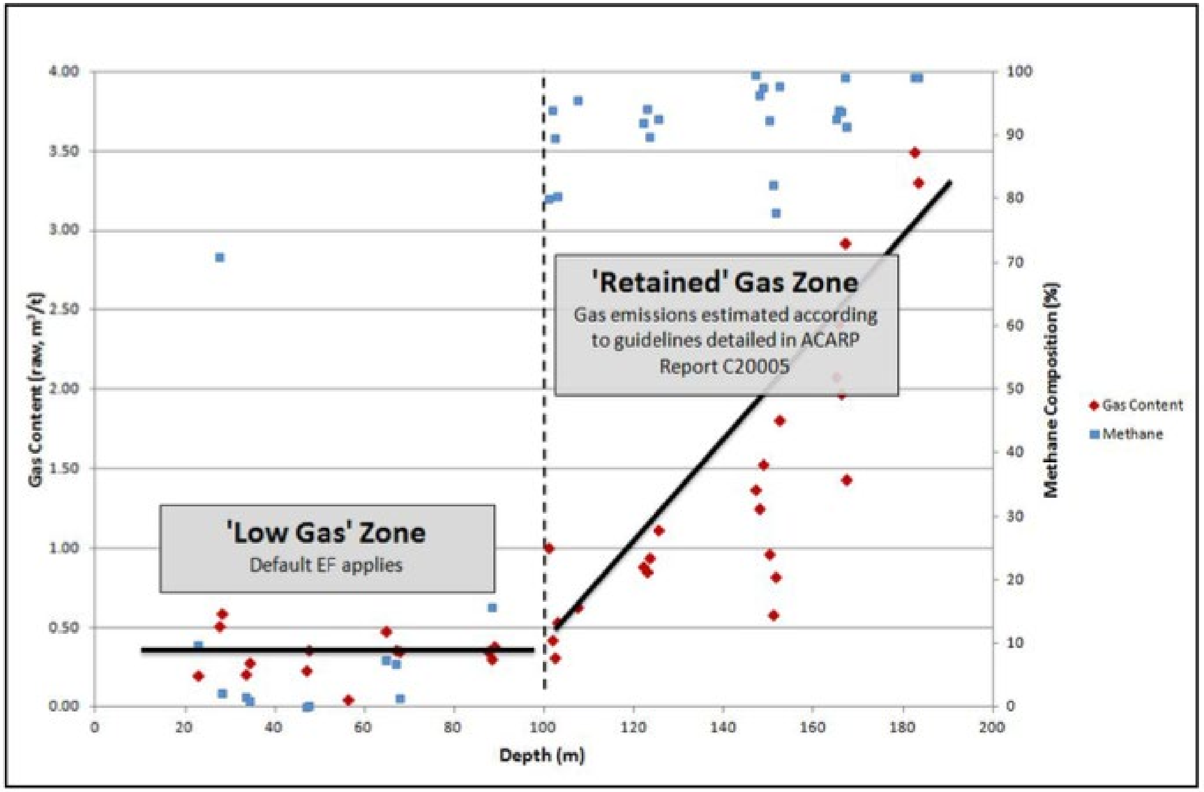
Overview of Australia’s Methodology

- Australia’s methodology for estimating methane emissions from surface coal mines uses a Tier 2/3 method and is the most specific.
  - For each mine, levels of strata with similar methane content are identified and total methane released in each bearing strata is calculated and summed.
  - For each level/domain, a minimum of 3 boreholes are located to capture the full variance of the gas trends with depth. The ultimate number of boreholes required at any deposit will be determined by data analysis methods.
  - A model is built to estimate the relationship of gas content vs depth, gas composition vs depth, gas content vs relative density (RD) and/or ash.
  - For estimating gas content, the Low Gas Zone is delineated and assigned a default emission factor (EF) of 0.00023.
  - Uncertainty of the Low-Gas Zone is assumed to be 50%.
  - Additional information involving the Australian methodology can be found in the Australian Coal Industry’s Research Program’s (ACARP) [Guidelines for the Implementation of NGER Method 2 or 3 for Open Cut Coal Mine Fugitive GHG Emissions Reporting](#).



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Testing the Approach

- We tested this approach for other blocks in the other coal field.
- The following slide shows gas content versus depth graphs for the Dharmabandh, Kapuria, Madhuband coal blocks in the Jharia coalfield.
  - Using gas content data collected by CMPDI, gas content versus depth curves were constructed for the three coal blocks, and then gas contents were calculated based on the regression equations.

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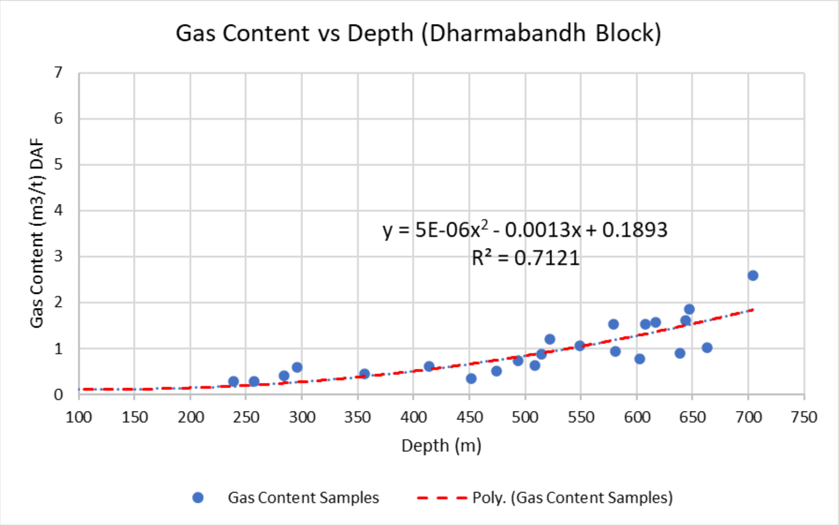
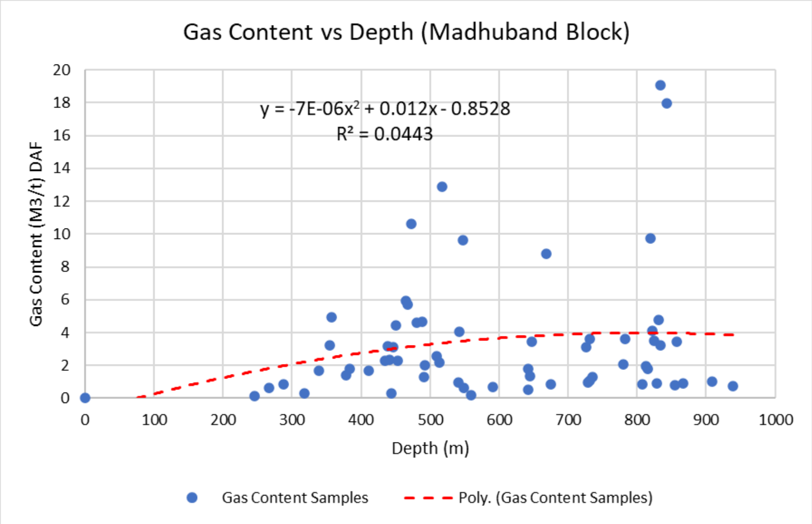
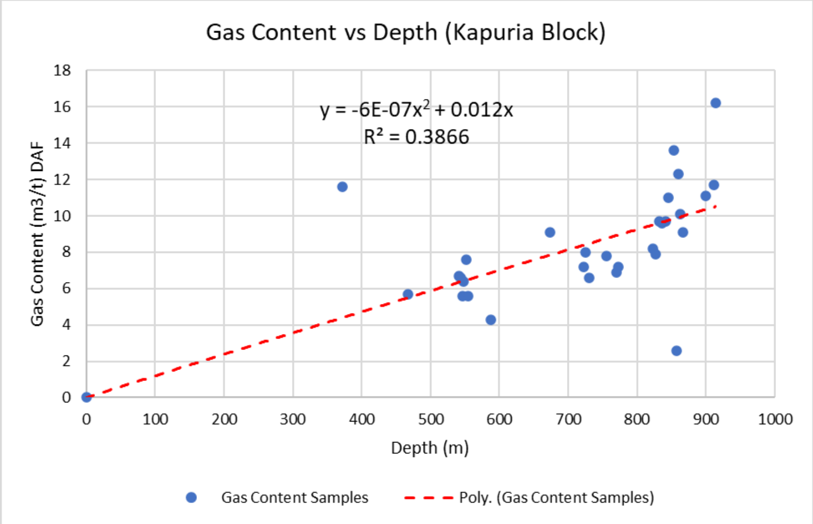
Gas Content vs. Depth for Three Coal Blocks in the Jharia Coalfield

- The team estimated gas content for three other blocks in the Jharia coalfield: Dharmabandh, Kapuria, Madhuband coal blocks. Using gas content data acquired by CMPDI, gas content versus depth curves were constructed for the three coal blocks, and then gas contents were calculated based on the regression equations.







Dharmabandh Block	
Depth (m)	Gas Content (m^3/t)
50	0.14
100	0.11
150	0.11
200	0.13
250	0.18
300	0.25

Madhuband Block	
Depth (m)	Gas Content (m^3/t)
50	-0.27
100	0.28
150	0.79
200	1.27
250	1.71
300	2.12

Kapuria Block	
Depth (m)	Gas Content (m^3/t)
50	0.60
100	1.19
150	1.79
200	2.38
250	2.96
300	3.55

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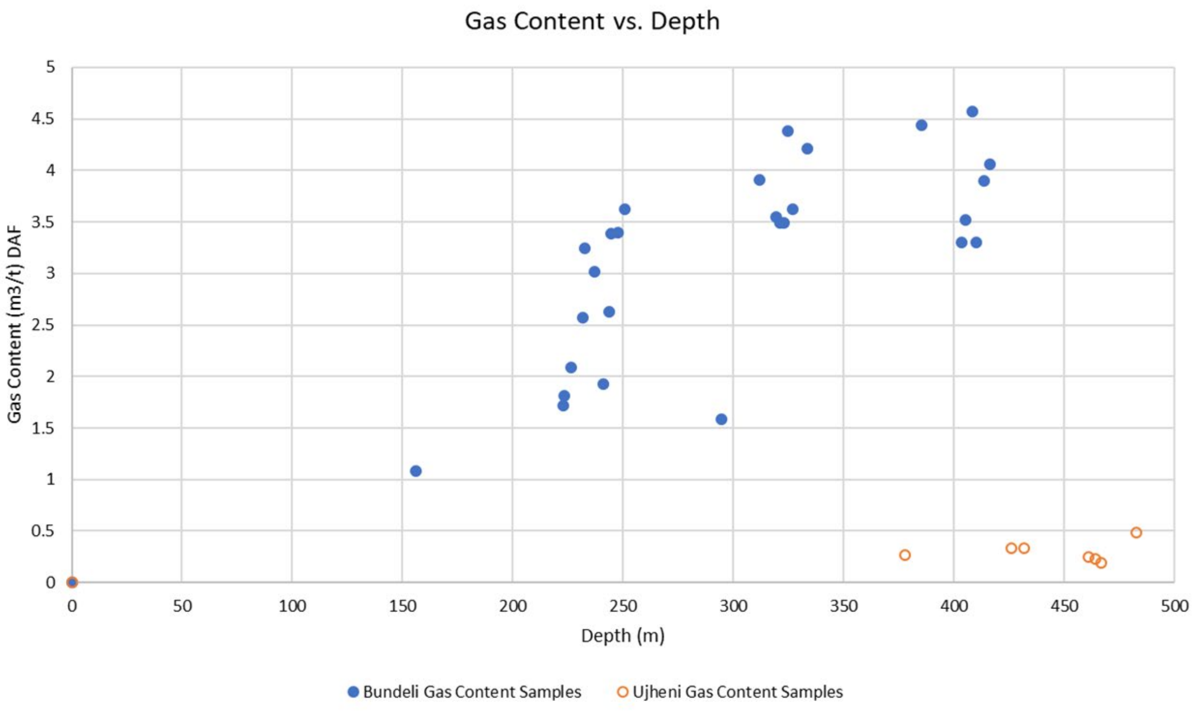
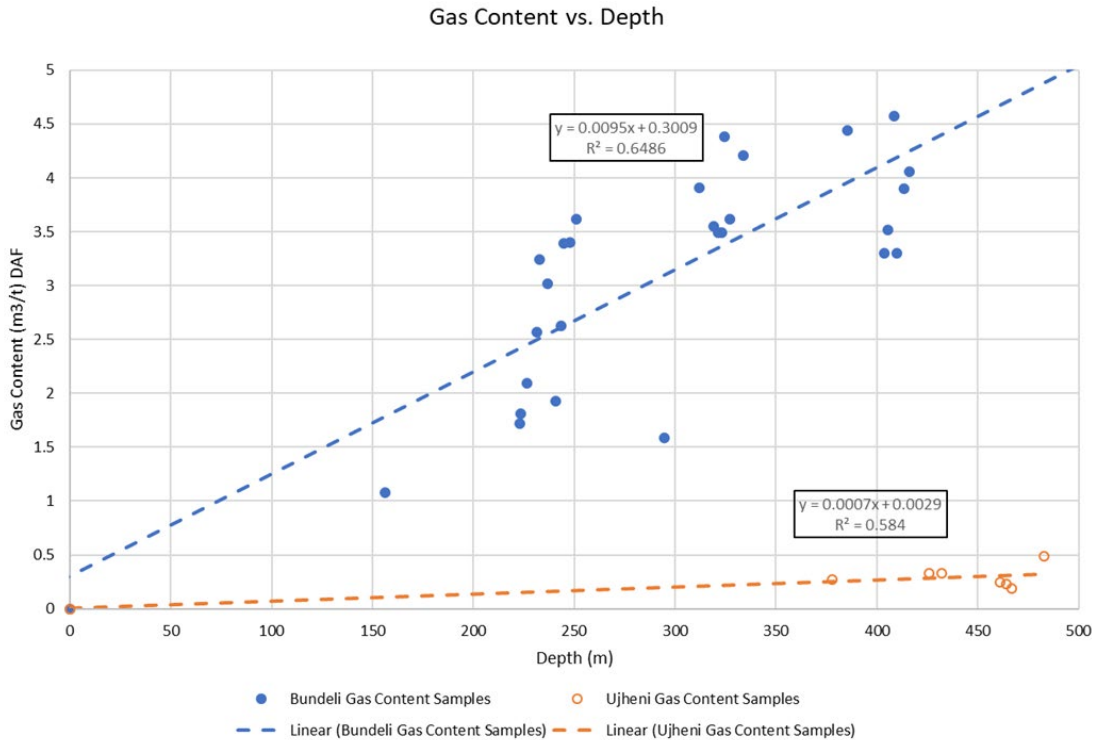
Key Takeaways

- Coal mines can vary significantly in terms of gas content within a coal basin, which can lead to inaccurate methane emissions estimates depending on the methodology used.
- The figure to the right displays gas content versus depth data for two coal blocks within the same coal basin.
- Generally, gas content increases with depth and it is assumed that gas content at 0 m is 0 m^3/t.
  - Still, applying a regression does not necessarily mean that a gas content of 0 m^3/t will be calculated at a depth 0 m.
  - Additionally, adding an artificial data point at 0,0 does not mean that a regression will intersect 0,0, and it can affect how well a regression fits the data.



Roadblocks

- A major challenge encountered in estimating methane emissions from surface coal mines in India is the lack of data at shallow depths, which is where most of the mining takes place.
  - Note that the samples taken from the three coal blocks in the Jharia coal field were all taken above 200 m.
  - This may be a result of equipment and sampling procedure limitation.
- What type of regression should be applied?
- The figure to the right shows the graph from the previous slide with linear regressions added to each data set.
  - Note that neither of the regressions intersect the y-intercept at 0,0 and they calculate different gas contents at the same depth.



Bundeli	
Depth (m)	Gas Content (m^3/t)
50	0.776
100	1.251
150	1.726
200	2.201

Ujheni	
Depth (m)	Gas Content (m^3/t)
50	0.038
100	0.073
150	0.108
200	0.143

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Conclusion

- The data collected by CMPDI demonstrates that gas content can vary within the same coal basin. Coupled with a lack of data collected at lower depths, caution must be taken when selecting a methodology for estimating methane emissions from surface coal mines.
  - Datasets taken from different locations within a coal basin will calculate gas content differently, and thus estimate methane emissions differently.
  - Variation in gas content may explain why employing remote sensing techniques such as satellites to detect methane emissions at specific surface coal mines may yields different results than using emissions inventories.
- Careful consideration must be taken in choosing which type of regression equation to apply to a given dataset.
- Using seam-specific data to estimate methane emissions from surface coal mines allows for emissions to be calculated at a more granular level than using an emissions multiplier.