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Estimation of AMM Resources and Reserves in the Upper Silesian Coal Basin – the Necessity of Change

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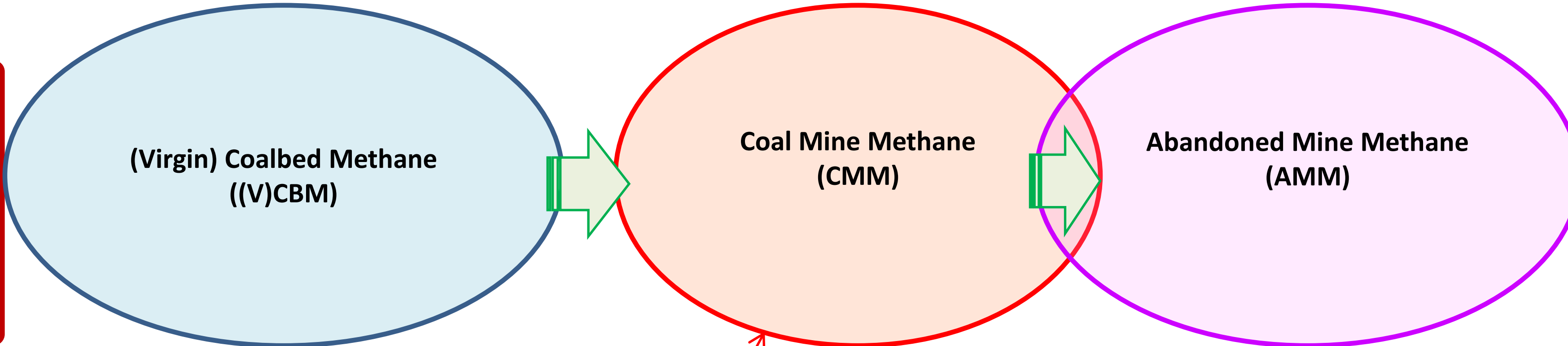
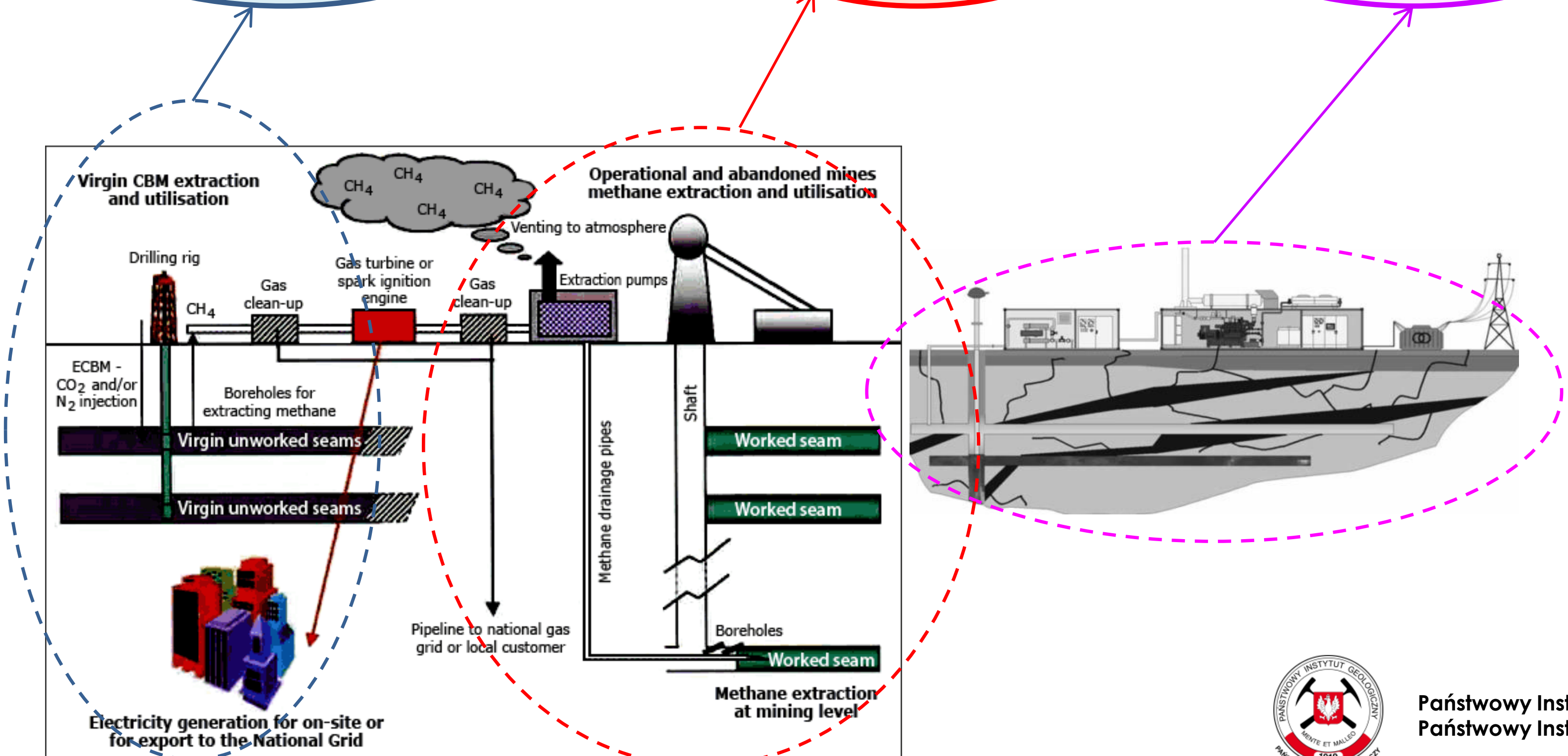
Coal-derived Methane Accumulations

Natural Gas Accumulations

Anthropogenic Gas Accumulations





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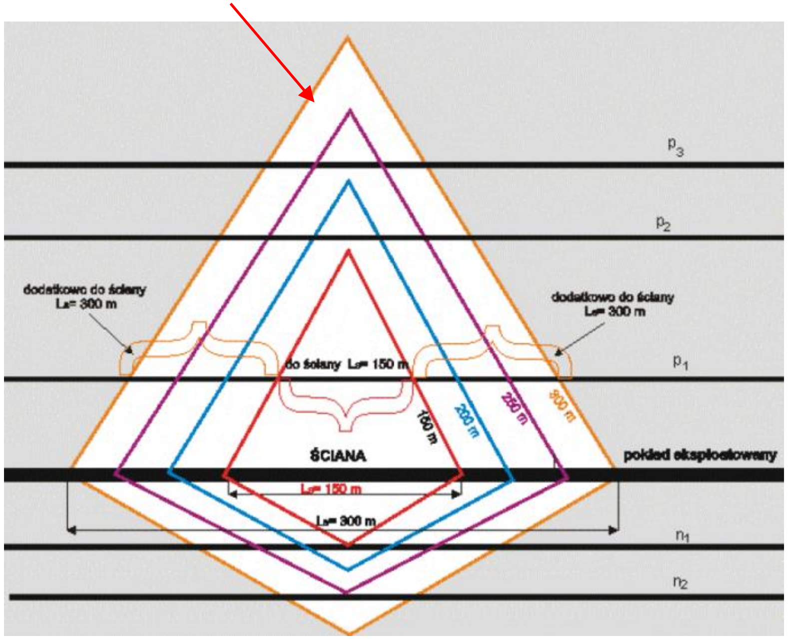
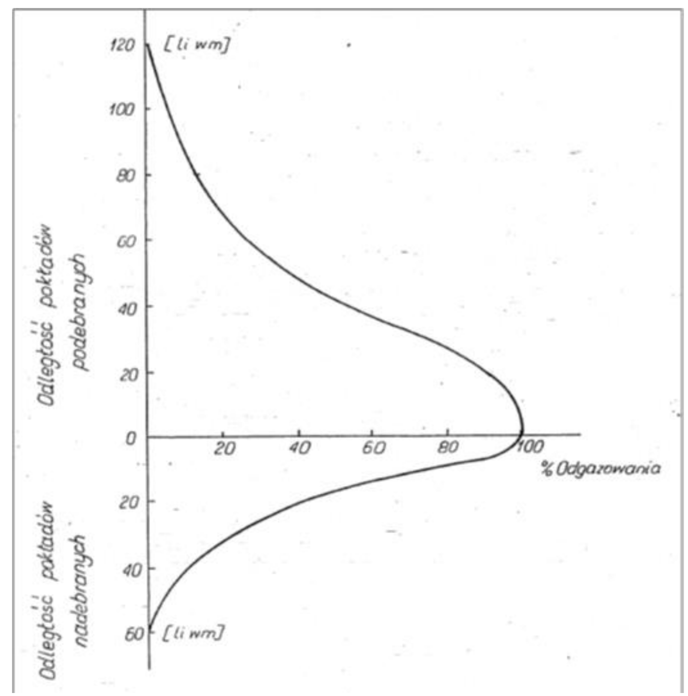
Origin of CMM and AMM

- Methane is released from coal seams as a result of desorption and diffusion in response to reservoir pressure reduction.
- The desorbable methane is released, while the residual methane is trapped in the coal reservoir.
- The desorbable methane is released from overlying and underlying coal seams within the zone of relaxation, and the level of seam degassing is time dependent.
- As the reservoir pressure of coal seams is being restored (flooding), the gas desorption is stopped.

Zone of relaxation – high permeability



Extent of relaxation and degassing of overlying and underlying coal seams in the longwall area (Krauze i in., 2017)



The degassing curves of overlying and underlying coal seams at the end of longwall coal extraction according to Stuffken

Existing Approach to AMM Resources and Reserves Estimation

- The Polish regulations divide coal-derived methane resources in two formal categories:
  - Main mineral resource (=> VCBM) which is under the oil and gas regulatory regime in terms of its exploration and production;
  - Accompanying mineral resource (=> CMM) which is under the coal regulatory regime in terms of its exploration and production.
- AMM accumulations have been categorized as „Main mineral resource" (AMM = VCBM), which leads to negative consequences in the estimation of AMM resources.
- The existing approach to AMM evaluation:
  - ✓ Recoverable resources are estimated using the following formula:

$$QMt = QMs + QMd$$

QMs – free methane gas resources (in gobs, workings and porous rocks)

QMd – desorbable methane gas resources (remaining after coal extraction) is usually an order of magnitude greater than free gas resources.

  - ✓ AMM reserves are estimated based on gas production forecast using surface-to-gob wells.

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Drawbacks of the Existing Approach to AMM Estimation

- **When estimating desorbable methane resources, the zone of effective methane drainage (de-stressed zone), which is the real source of methane emission, is not determined.**

  Instead, <u>methane is supposed to be recovered from the whole coal deposit area,</u>

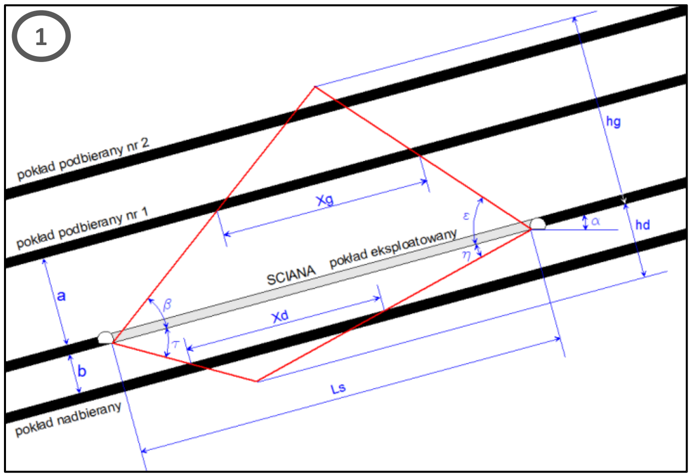
  including methane contained in low permeability coal seams, occurring outside of the de-stressed zone (areas undisturbed by mining), which is unlikely to be produced using surface-to-gob wells.

- **The remaining desorbable methane resources are estimated using the average methane content of coal obtained from methane content measurements of partially degassed coal seams in underground workings, which is unreliable.**

- **After coal extraction is terminated, methane emission rates decline rapidly, which is not taken into consideration in reserves estimation.**

Modifications to the Existing AMM Estimation Methodology – (1) Definition of Methane Drainage Boundaries in Three Steps

Determination of a de-stressed zone for the longwall – cross-section

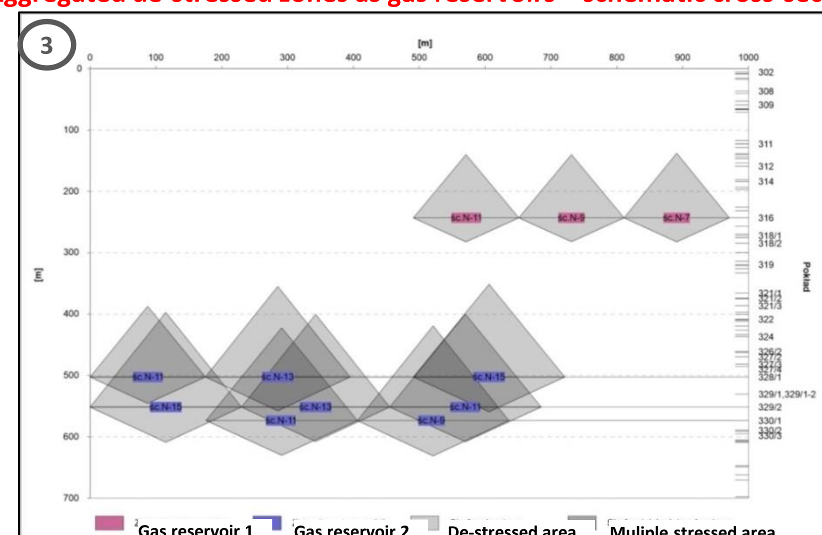


1) Geometry of de-stressed zones around long-walls, determined using the CMI methodology.

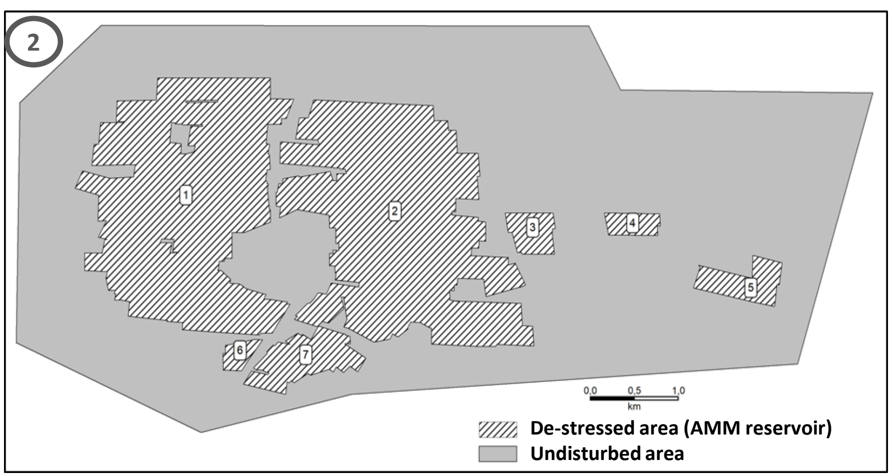
2) Destressed zones are grouped into estimation areas in planar view.

3) Gas reservoir – aggregated de-stressed zones which are hydraulically connected enabling gas drainage.

Aggregated de-stressed zones as gas reservoirs – schematic cross-section



Delineation of estimation areas – planar view



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Modifications to the Existing AMM Estimation Methodology – (2) Estimation of the Remianing Desorbable Methane

- **Alternative method of desorbable methane estimation has been proposed in view of the fact that there are no reliable methods of estimating the methane content of partially degassed coal seams.**

Assuming that the only source of desorbable methane are coal seams within the de-stressed zone, the remaining desorbable methane resources <u>(*QMd*) are estimated as the difference between the original coalbed methane resources before mining (*QMo*) and the total emission of methane during and after mining (*Ec*):</u>

$$QMd = QMo - Ec$$

- **Original desorbable methane resources (*QMo*) are estimated as the product of the original methane conent of coal and the original coal resources within the de-stressed zone.**

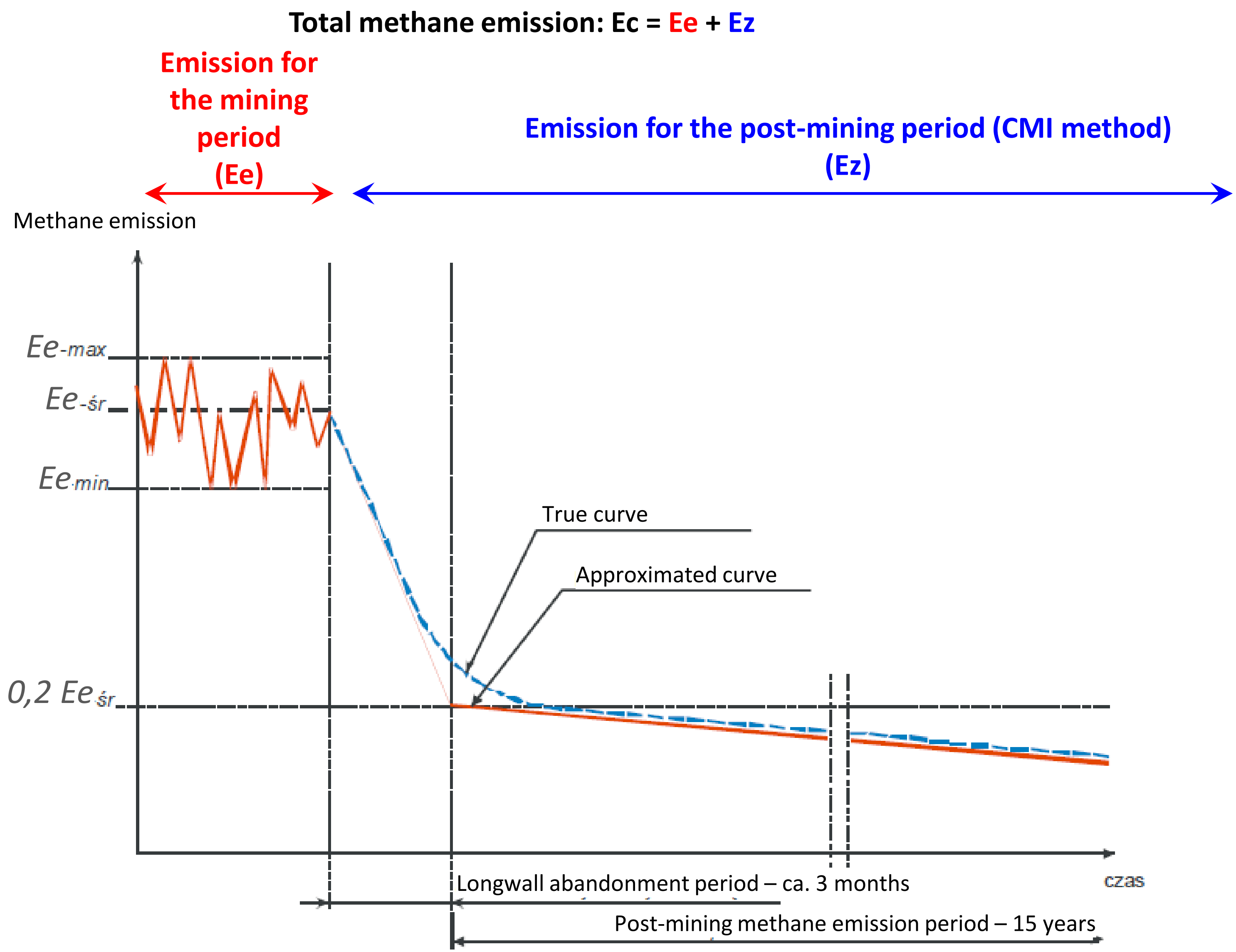
- **Total emission of methane:** $Ec = Ee + Ez$

  Ee – methane emission recorded during the mining period

  Ez – methane emission estimated for the post-mining period (estimation procedures according to the CMI methodology)

Methane emission estimates are performed for each individual longwall and summed up.

Total Emission Estimates – Forecast of Methane Emission to Gobs



Model of methane emission to gobs for a longwall

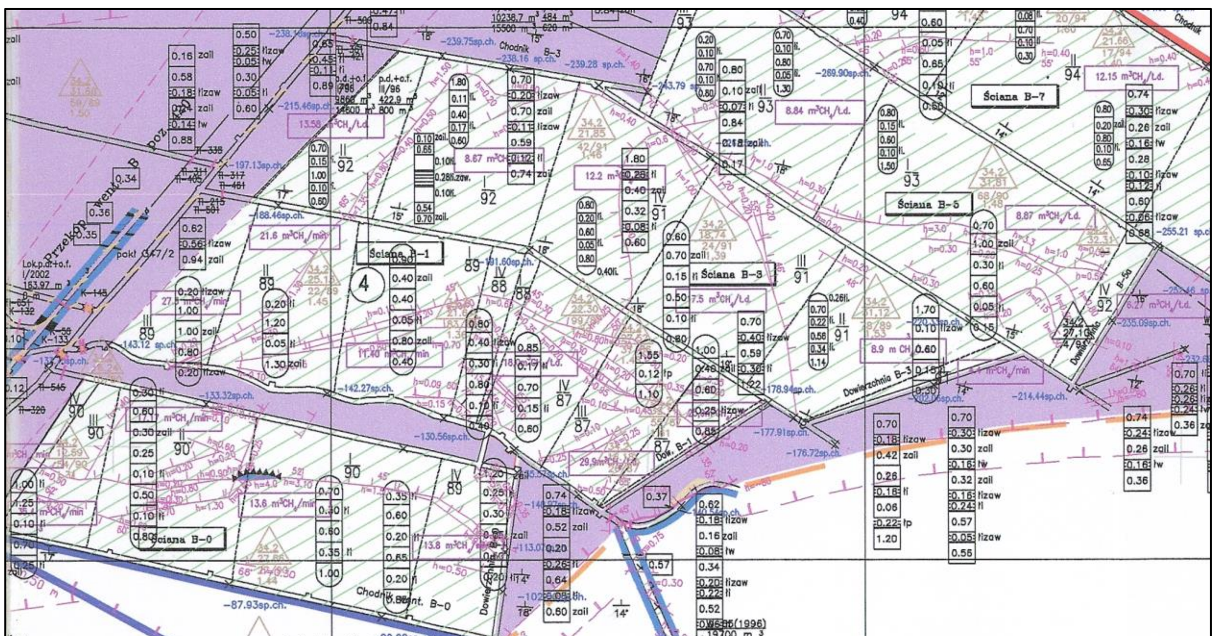
(after Krause and Łukowicz, 2012)

Application of the Modified Approach – Case Study

- Methane resources was estimated for the recently closed Krupiński coal mine, in which 16 gassy coal seams were mined between 1983 and 2017, within the depth interval from 140 m to 1050 m.
- AMM drainage boundaries were defined (extent of the de-stressed zone) for all 132 longwalls and 17 hydraulically isolated gas reservoirs were delineated.
- The original desorbable methane resources of coal seams within the de-stressed zone (QMo) were estimated on the basis of methane content data from coreholes drilled before coal mining, supplemented with methane content data from mine workings and underground boreholes [∑QMo = 758 million m^3]
- Total methane emission (Ec) was estimated for the mining period (Ee) and for the post-mining period (Ez) [∑Ec = 2 049 million m^3].
- *QMd = QMo – Ec < 0   !!!*

The Main Findings of the Case Study

- **Total methane emission(*Ec*) was almost 3 times greater than the original desorbable methane content within the de-stressed zone (*QMo*).**
- **It was estimated that only about 40% of the original coal resources, which had been the source of the total methane emission, occurred within the postulated de-stressed zone.**
- **Most probably, additional gas drainage pathways exist, spreading beyond the postulated de-stressed zone, in connection with the permeable zones of tectonic fractures reactivated or induced by mining.**
- **Numerous faults and fractures are known to occur in the Krupiński mine, especially in the vicinity of the Żory-Jawiszowice fault zone which is one of the biggest faults in the USCB.**

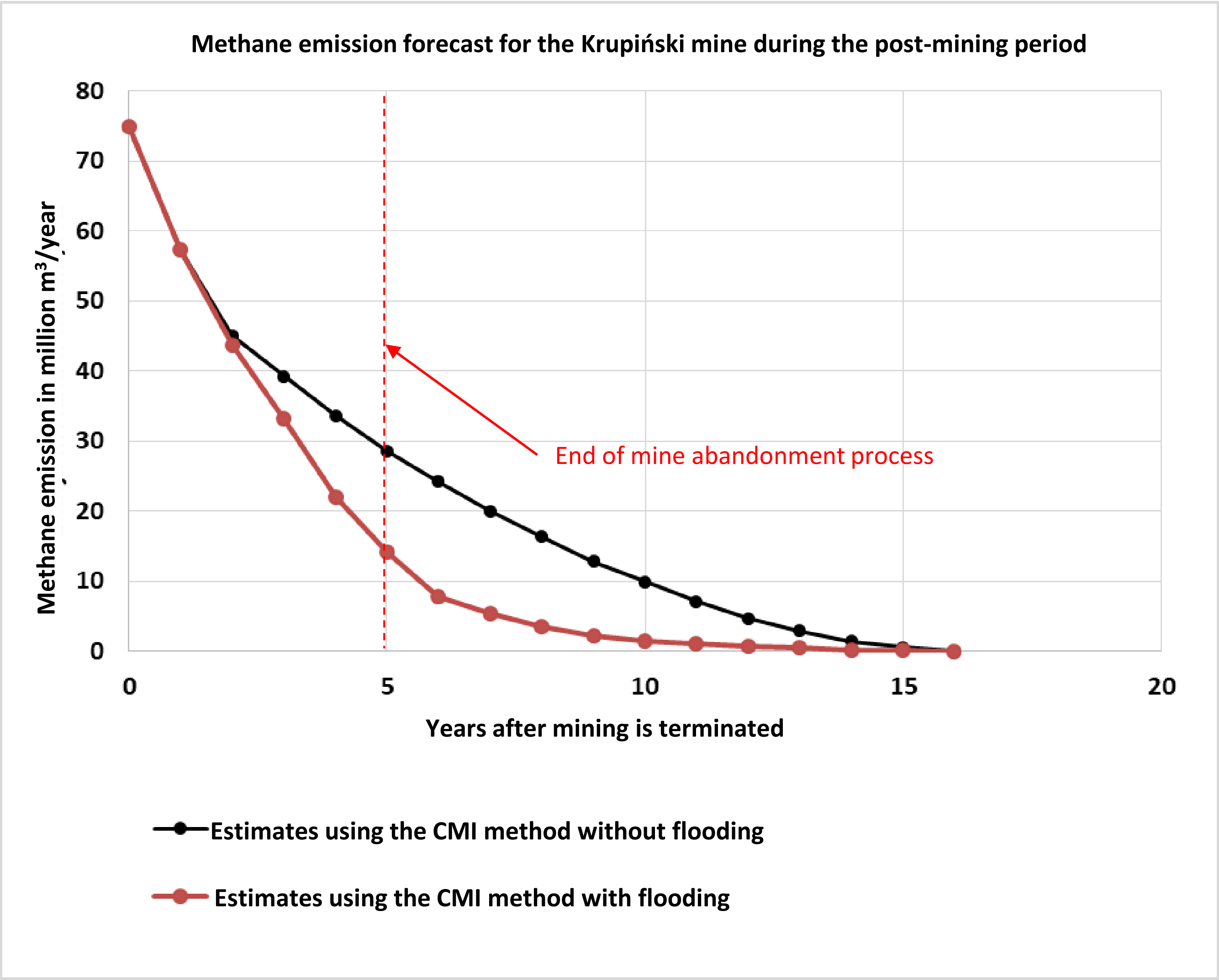


Fragment of the Krupiński mining map with longwalls cut by numerous faults

New Methodology of AMM Resource Estimation

- Due to a very complex network of permeable tectonic fractures, the extent of gas drainage zones cannot be determined with acceptable accuracy.
- Under such circumstances, the recoverable (desorbable) methane resources of the abandoned mine cannot be determined using volumetric methods and a new approach must be adopted.
- Therefore, it is assumed that the estimated ultimate recovery (EUR) of CMM + AMM is equal to the total emission of methane during the mining period and the post-mining period.
- The remaining recoverable resources of AMM is that part of EUR which is obtained based on the post-mining emission forecast conducted for a given initial date (e.g. coal mining termination date or mine abandonment date).

AMM Recoverable Resources – Methane Emission Forecast



Methane emission forecast without flooding – 246 million m^3

Methane emission forecast with flooding – 135 million m^3

Methane emission after the end of mine abandonment – ca. 30 million m^3

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Summary

- Modification of the existing methodology of AMM resource estimation and its application as a case study of the recently closed gassy coal mine did not bring expected results due to the existence of additional gas drainage pathways, extending beyond the postulated destressed zone, which cannot be identified with acceptable accuracy.

- Volumetric methods cannot be used for the remaining desorbable gas estimates, and, consequently, the existing approach to AMM resource estimation has to be changed radically.

- It is proposed that the remaining recoverable AMM resources will be determined using a dynamic method of gas volume estimation based on methane emission forecast for the post-mining period.

- In the case of the Krupiński mine, the AMM recoverable resources was calculated as the total methane volume estimated for each individual longwall using the CMI methodology. Other methods of AMM volume estimates can also be applied e.g. a decline curve method.

- AMM reserves estimation (actual gas production forecast) must take into consideration additional factors, such as: mine abandonment process, potential usage of the existing mine drainage system as well as configuration and efficiency of the planned surface-to-gobs production wells.


Thank you for your attention