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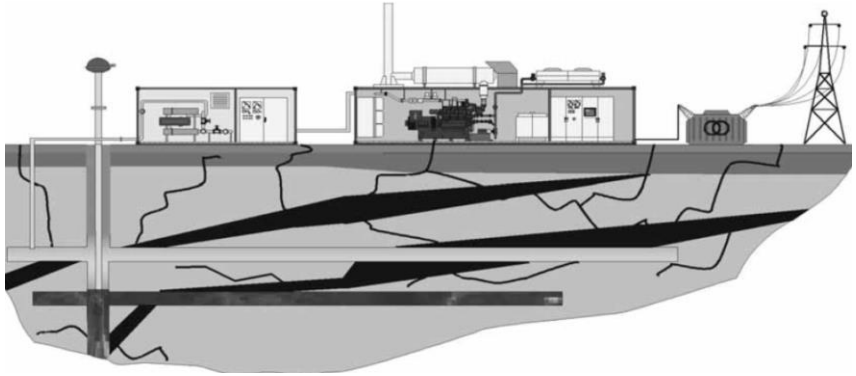
AMM Resource and Reserves Assessment – Polish Experience



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Regulatory Framework for Evaluating Resources/Reserves of Coalbed Methane as ”Main Mineral” (CBM/AMM)

- Geological and Mining Law (GML) governs mineral exploration and production activities as well as resource/reserves evaluation, including petroleum.
- GML differentiates between coalbed methane as „main mineral” (CBM or VCBM) and coalbed methane as „accompanying mineral” (CMM).
- CBM is categorized as petroleum in GML.
- AMM is considered as CBM and thus petroleum regulations are applicable.
- CBM resource/reserves evaluation process is governed by the Regulation of the Minister of the Environment of July 1, 2015, concerning Geological-Investment Report for Petroleum Deposits.

Evaluating CBM Deposits Using ”Balance Criteria”

- **Boundaries of a mineral deposit have to be delineated using the <u>prescribed cut-off values of reservoir parameters defining the deposit</u> (also called <u>”balance criteria”)</u> as stated in the applicable regulations.**
- ***Modifications of ”balance criteria” are permitted if special geological conditions are encountered, but it has to be justified.***
- ***”Balance criteria” for AMM are usually modified.***

Prescribed cut-off values of reservoir parameters defining the CBM/AMM and CMM deposits

#	Reservoir parameter defining the deposit	Unit	Prescribed cut-off value	
			CBM/AMM	CMM
1.	Maximum depth for resource/reserves evaluation	m	1500 (AMM – water level depth)	Limited by the depth of the coal deposit
2.	Minimum methane content for delineating deposit boundaries	$m^3/t(daf)$	4,5 ← AMM	2,5
3.	Minimum average methane content	$m^3/t(daf)$	Greater than the residual methane content	Greater than the residual methane content
4.	Minimum coal seam thickness	m	0,6 ← AMM	0,1

Remark: Possible modifications for AMM – red fonts

Polish Classification of CBM Resources (Assessing Economic Value)

- **Geological-Investment Report on petroleum deposits (specifically CBM) should include estimation of resources broken down into the following classes:**
  - ***"Balance" resources** – as estimated <u>within</u> CBM reservoir boundaries defined by „balance criteria".*
  - ***"Sub-balance" resources** – as estimated outside of the reservoir boundaries which are defined by „balance criteria".*
  - ***Recoverable resources** – part of CBM resources that can be technically recovered.*
  - ***"Industrial" resources (Reserves)** – part of CBM resources, within the boundaries of the planned mining area designated for development, which are technically and economically feasible to extract, taking into account environmental protection requirements.*
  - ***"Non-industrial" resources** – part of CBM resources not classified as "industrial" resources, which may become feasible to extract in future.*

Resources/Reserves of CBM as „Main mineral" in the USCB (according to Mineral Yearbook of Poland, as of 31 Dec 2018)

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	Lp.	Nazwa złoża *Deposit name*	Stan zag. złoża	Zasoby wydobywalne bilansowe / pozabilansowe [p] *Recoverable resources [MMm³]*			Zasoby przemysłowe *Reserves [MMm³]*	Emisja z wentylacją	Wydobycie (odmetanowanie) *Production [MMm³]*
				Razem *Total [MMm³]*	A+B	C			
	w tym: złoża metanu jako kopaliny głównej w złożu: złóż: 11			26 133.34 10 998.00 [p]	513.58 95.10 [p]	25 619.76 10 902.90 [p]	151.08	-	5.22
	1	Halemba II	R	1 216.00	-	1 216.00	-	-	-
AMM	2	Jankowice-Wschód	E	15.83 9.79 [p]	- - [p]	15.83 9.79 [p]	15.57	-	0.64
AMM	3	Kaczyce I	E	38.87	-	38.87	6.22	-	1.25
	4	Lędziny	R	12 444.80 3 191.50 [p]	- - [p]	12 444.80 3 191.50 [p]	-	-	
AMM	5	Mszana	P	57.40	-	57.40	-	-	-
	6	Murcki (głębokie)	P	6 568.50 6 306.50 [p]	- - [p]	6 568.50 6 306.50 [p]	-	-	-
	7	Paniowy-Mikołów-Panewniki	P	1 394.40 1 012.30 [p]	- - [p]	1 394.40 1 012.30 [p]	-	-	-
	8	Silesia Głęboka	Z	2 791.15 467.73 [p]	513.58 95.10 [p]	2 277.57 372.63 [p]	-	-	-
AMM	9	Wilchwy	P	57.17 10.18 [p]	- - [p]	57.17 10.18 [p]	51.56	-	-
	10	Zebrzydowice	P	1 424.75	-	1 424.75	-	-	-
AMM	11	Żory 1	E	124.47	-	124.47	77.73	-	3.33

E – złoże eksploatowane ← CBM production
P – złoże o zasobach rozpoznanych wstępnie (w kat. C)
R – złoże o zasobach rozpoznanych szczegółowo (w kat. A + B)
Known deposits in different categories of geological assurance
Z – złoże, z którego wydobycie zostało zaniechane CBM production terminated

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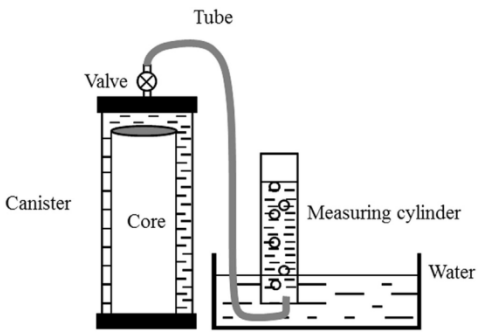
Estimating CBM Resources for the Undeveloped Coal Fields (VCBM Resources)

- **Assumption: <u>100% adsorbed gas</u>, virgin coal seams.**
- **CBM reservoir boundaries definition: the spatial extent of coal seams with methane content >=4,5 m^3/t(daf), to the maximum depth of 1500 m.**
- **Coal seams thickness >= 0,6 m.**
- **CBM resources are estimated using a volumetric method of to determine:**
  - ✓ **Gas-in-Place – total amount of methane**
  - ✓ **Balance-recoverable resources – desorbable methane:**

    $$Qm = (M - Mr) * Qw * w_1 * w_2$$

    where:
    M – average methane content [m^3/t],
    Mr – residual methane content [m^3/t],
    Qw – coal resources within the CBM deposit boundaries [t],
    w_1 , w_2 – conversion factors accounting for ash and moisture



- **Methane content is measured using the Polish mining method or, sporadically, USBM method.**

Estimating Balance-Recoverable Resources of AMM

- **Assumptions:**
  - ✓ **gas occurs as free gas within the de-stressed zone, and adsorbed gas of coal seams;**
  - ✓ **the abandoned mine is flooded;**
  - ✓ **all gassy coal seams with thickness exceeding 0,1 m are included;**
  - ✓ **resources are estimated to the water level depth.**
- **Balance-recoverable resource estimation formula:**

$$Qm = Qs + Qd$$

  - ✓ ***Qs* (static resources) – free gas trapped in the gob zone, abandoned workings and porous rocks;**
  - ✓ ***Qd* (dynamic resources) – desorbable methane in all the remaining gassy coal seams.**
- **Free methane gas (static) resources estimation formula:** $Qs = Vk*p*C*w_T$

  where:

  Vk – void volume of the reservoir filled with free gas [m³],

  p – gas pressure factor : the ratio of reservoir pressure to standard atmospheric pressure,

  C – CH_4 content in gas [fraction],

  w_T – STP conversion factor
- **Desorbable gas (dynamic) resources is determined assuming that it is available within the whole area confined by the CBM reservoir boundaries, with the formula:** $Qd = (M - Mr)*Qw*w_1*w_2$

  where:

  M – average methane content [m³/t],

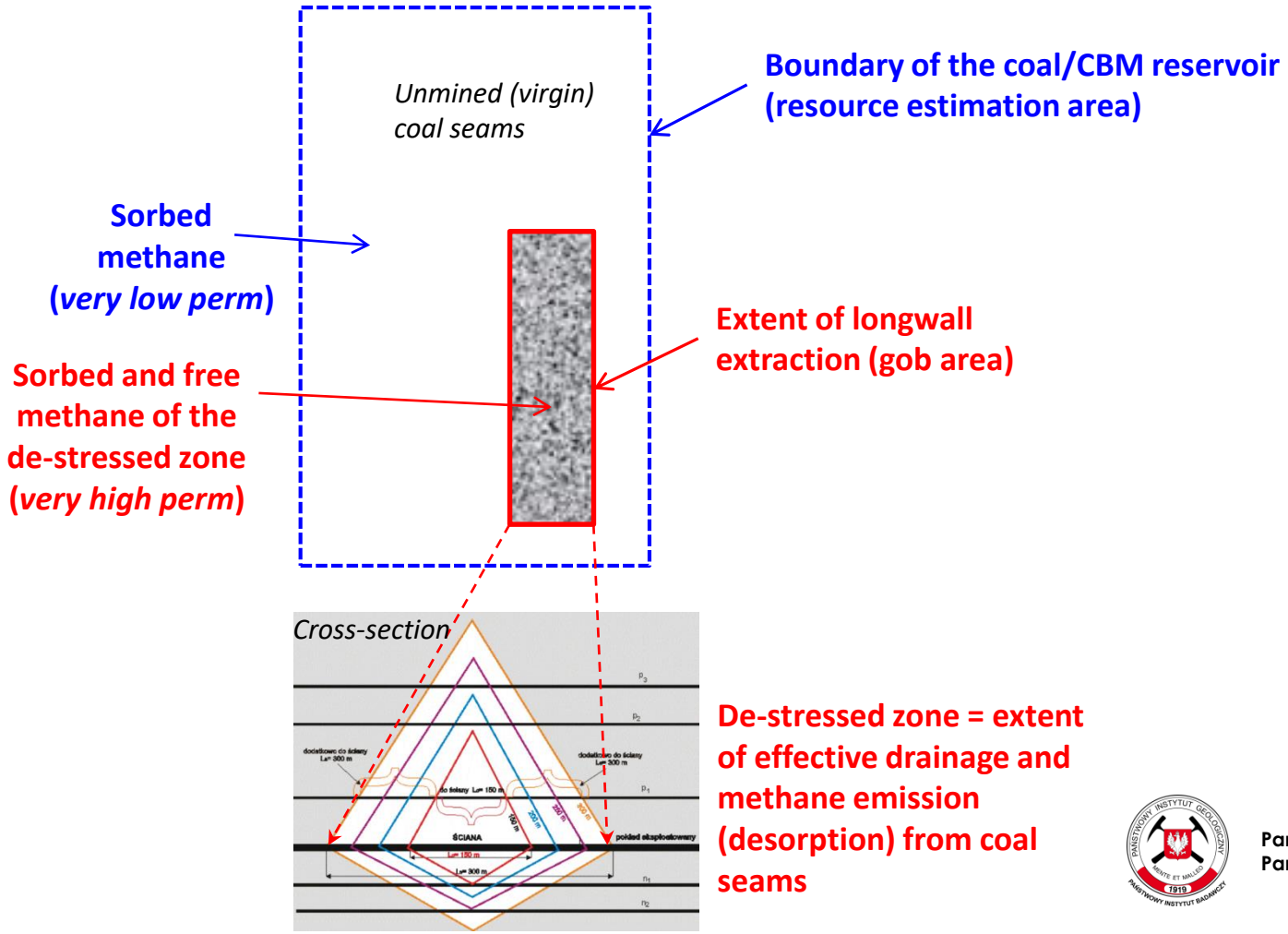
  Mr – residual methane content [m³/t],

  Qw – coal resources within the CBM deposit boundaries [t],

  w_1 , w_2 – conversion factors accounting for ash and moisture

Problem of Recoverable Desorbable CBM Resources

- It is assumed that desorbable gas of all coal seams (with gas content exceeding residual gas content) occurring above the water level, including virgin coal seams of the undisturbed zone, can be technically recoverable.
- In effect, AMM + VCBM resources are estimated.



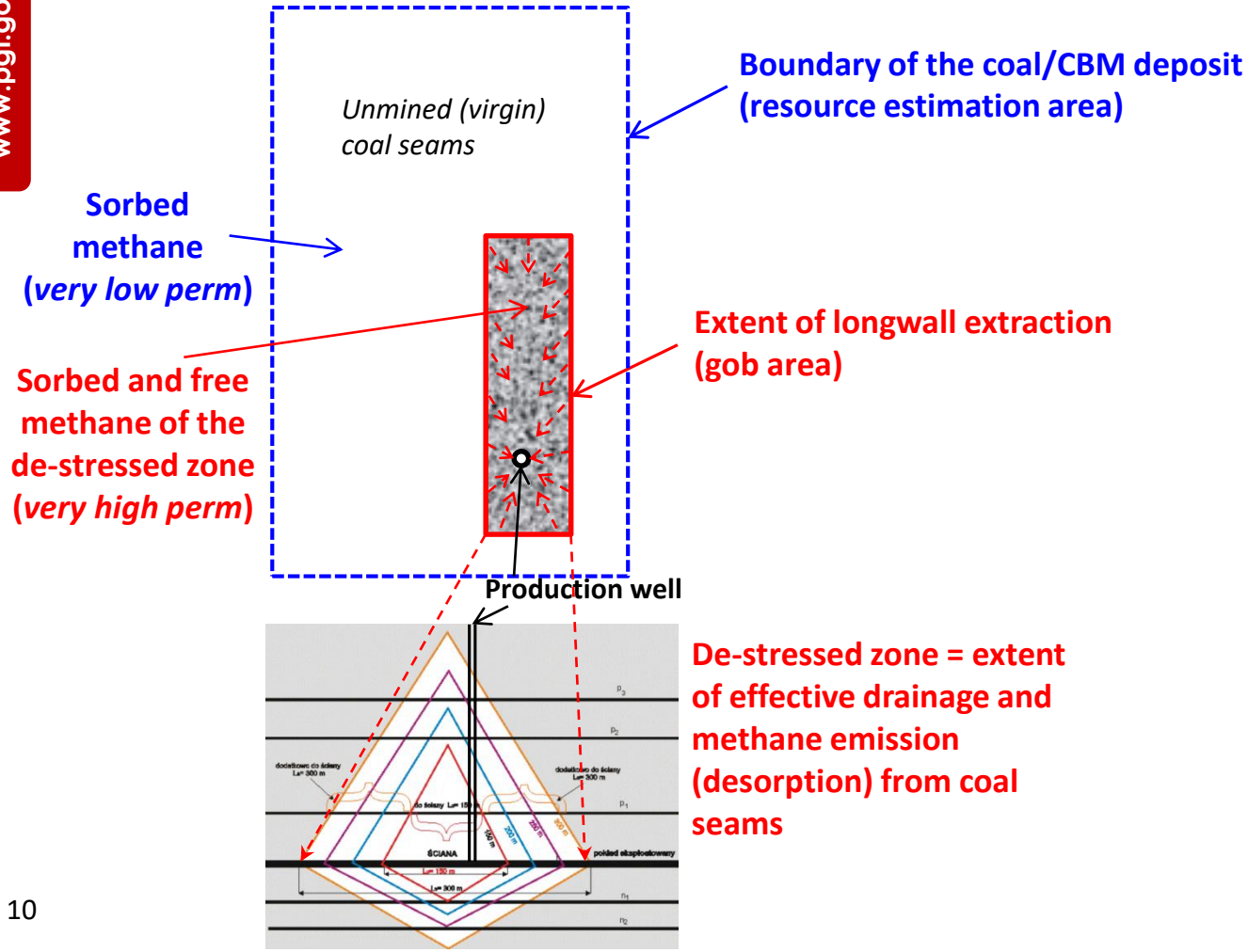
De-stressed zone = extent of effective drainage and methane emission (desorption) from coal seams

Estimating AMM Reserves

- **Assumptions for AMM reserves estimates:**
  - ✓ **Methane gas is captured with the use of surface wells to gob zones and extraction pump.**
  - ✓ **Gas production rate is supposed to remain <u>constant</u> and is predetermined based on the initial flow test and gas utilization options.**
  - ✓ **Duration of gas production is dependent on the <u>availability of recoverable resources</u> and the possibility of making profit on investment.**
  - ✓ **Any depletion of the initial free gas resources <u>will be compensated</u> by the gas desorbed from unmined coal seams (<u>even beyond the de-stressed zone</u>).**
- **The volume of AMM reserves is estimated based on gas production prediction provided sufficient amount of recoverable resources is available.**

Problem of AMM Reserves beyond the De-stressed Zone

- **Gas desorption and flow from unmined coal seams is likely to occur within the de-stressed zone and its immediate vicinity. (Difficulty recovering VCBM gas is also indicated by low permeability of coal seams in the USCB resulting in poor flow rates of the historical CBM wells).**
- **Unmined (virgin) coal seams beyond the de-stressed zone still need effective dewatering for gas desorption and gas drainage.**



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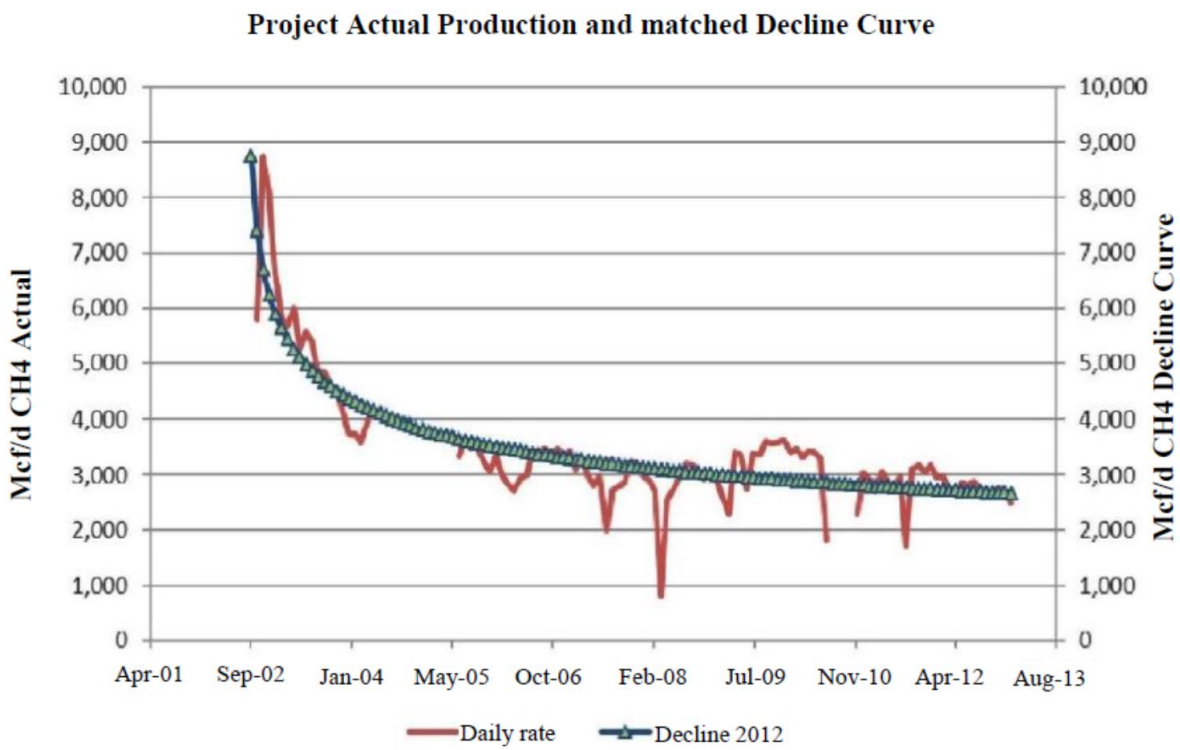
International Experience in AMM Resources/Reserves Estimation

„Best Practice Guidance for Effective Methane Recovery and Use from Abandoned Coal Mines" (UNECE, 2019)

Key messages for quantifying AMM reserves and predicting gas flow rates:

- **The reservoir boundaries are defined by the <u>extent of former longwall de-stressing zones</u> and the gas resource is the <u>gas remaining in unworked coal that has been disturbed by former longwall extraction</u>.**
- **The potential production gas flow rate can be estimated by using measured gas emission data from the mine before closure to extrapolate <u>exponential or hyperbolic decay curves</u>.**



Conclusions

- A process of determining AMM resource and reserves is governed by the Polish regulations tailored for VCBM, with some modifications.
- The recoverable resource is estimated as free gas (of the de-stressed zone) and desorbable gas within the CBM deposit boundaries usually extending well beyond the de-stressed zone. Thus, in effect, AMM+VCBM resources are estimated although it is unlikely that VCBM resources will be developed.
- AMM reserves are estimated based on predicted constant gas flow rates that could continue as long as the estimated recoverable resources (of AMM+VCBM) are not depleted. This approach does not take into account decreasing emissions of methane within the de-stressed zone as well as unlikelihood of reserves contribution from VCBM.
- It is recommended that a reliable methodology for AMM resources/reserves estimation will be developed along with appropriate changes in the Polish regulations.
- This is of paramount importance considering the high future potential of AMM in the Upper Silesian Basin (possible closures of gassy coal mines), which could be beneficial for the economy as well as safety and the environment.