GŁÓWNY INSTYTUT GÓRNICTWA

GIG

New Directions in R&D in order to decrease methane hazard and to increase CMM capture - based on GIG experience

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Experimental mine „Barbara”
Department of Gas Hazard Control

School of Underground Mining

Typical problems at gassy coal mines

- Ventilation and Gas Emissions Management in Coal Mines
- Development of Improved Methane Drainage Technologies by Stimulating Coal Seams for Major Risk Prevention and Increased Coal Output
- Monitoring, Assessment, Prevention and Mitigation of Rock Burst and Gas Outburst Hazards in Coal Mines
- Prediction and mitigation of methane explosion effects for improved protection of mine infrastructure and critical equipment

CMM related projects

- **AVENTO** (Ventilation and Gas Emissions Management in Coal Mines),
- **MAPROC** (Monitoring, Assessment, Prevention and Mitigation of Rock Burst and Gas Outburst Hazards in Coal Mines),
- **GASDRAIN** (Development of Improved Methane Drainage Technologies by Stimulating Coal Seams for Major Risk Prevention and Increased Coal Output),
- **EXPRO** (Prediction and mitigation of methane explosion effects for improved protection of mine infrastructure and critical equipment),
- **EPA2** (A first feasibility study for cost effective methane degassing and capture ahead of mining operations to reduce methane emissions in Poland during mining (Pawłowice 1 coal field).

AVENTO

Advanced Tools for Ventilation and Methane Emissions Control

Research Fund for Coal and Steel (RFCS)

AVENTO had four basic aims:

1. To develop **new concepts** on environmental (**methane** and **ventilation monitoring systems**), taking into account the new risks appearing in the current and future production fields, in order to improve the safety and climatic conditions at the working areas.

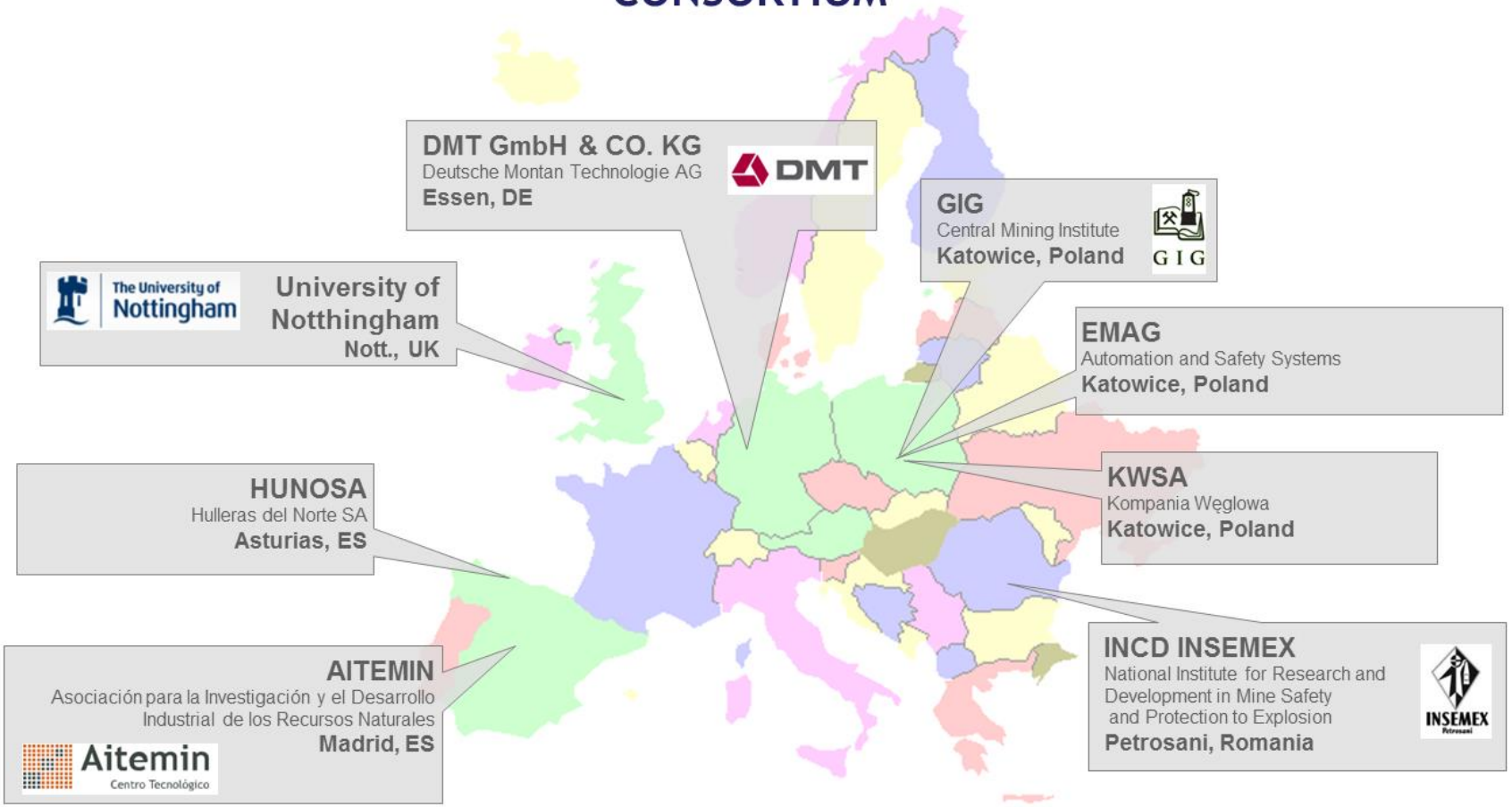
2. To use these new concepts for promoting a transition from a ***Prescriptive*** ventilation implementation / management model (fixed air flows have to be maintained) to a ***Performance- based*** one (*VOD* or *Ventilation on Demand*, supply the air when and in the amount actually needed).

3. To use these new concepts as an important aid to manage emergency / post-emergency situations: fires, fire-fighting, collapses, gas outburst and explosions, etc.

4. To **reduce the costs** involved in **ventilation**, analysing different aspects such as the dynamic regulation of air flow (the aforesaid *"Ventilation on Demand"*, and new systems of main fans control for better efficiency and reliability.

AVENTO

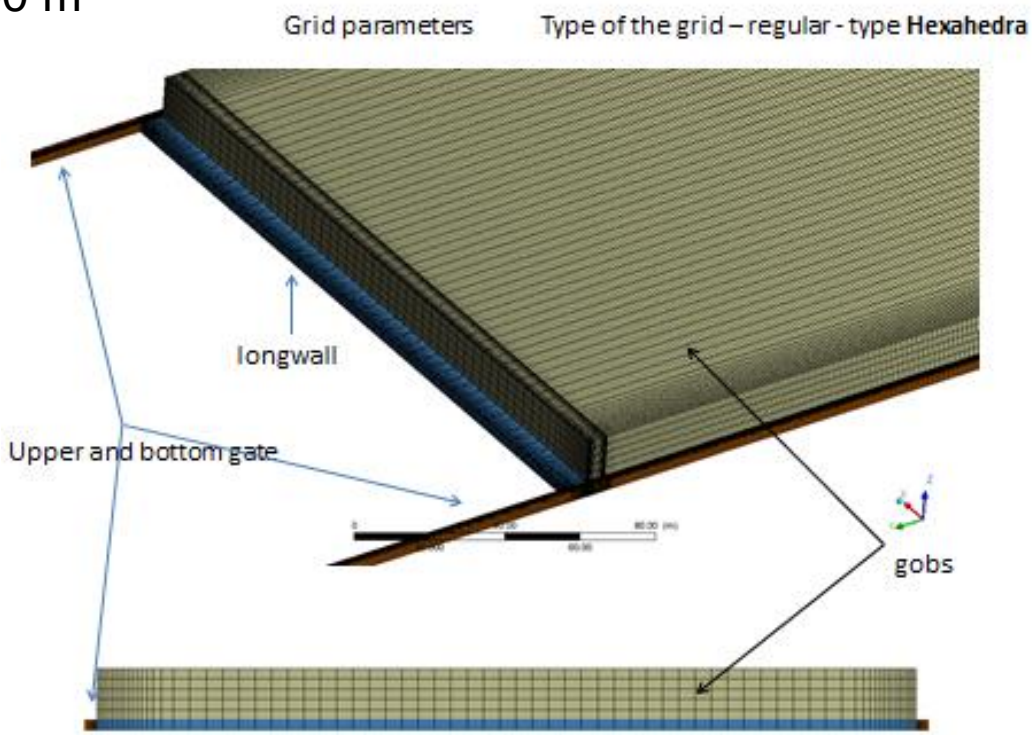
CONSORTIUM



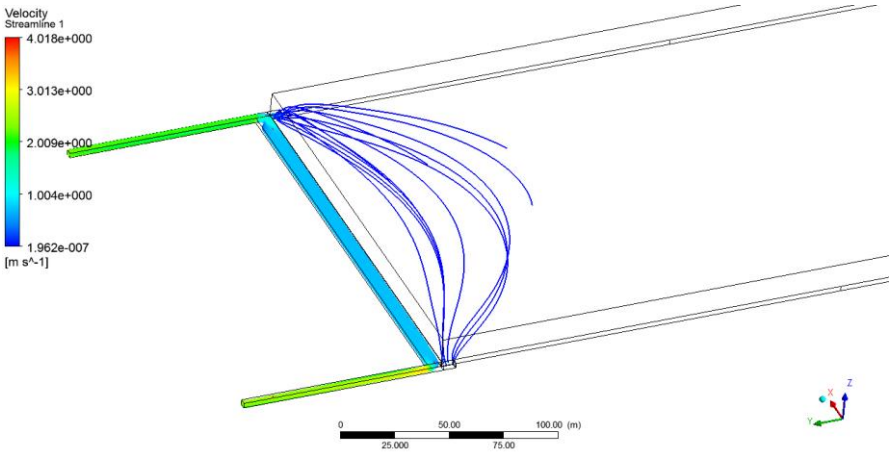
Discretization of the Model 3D nr 1 – variant ventilation of the longwall at Y

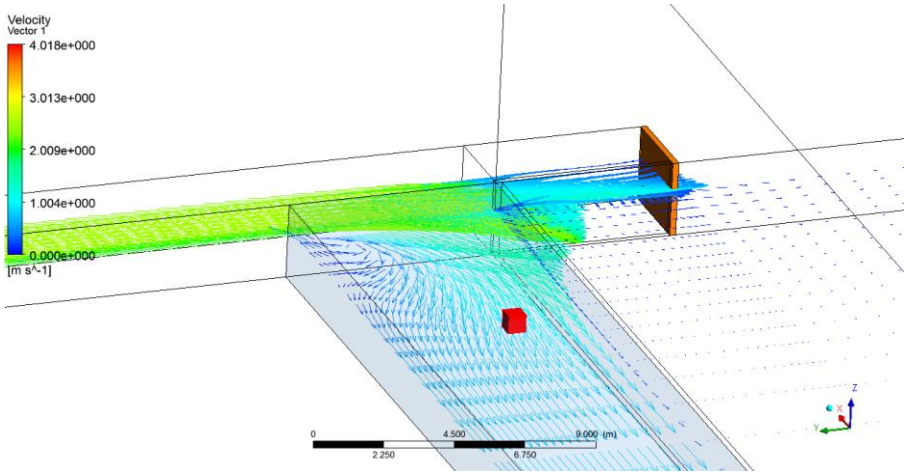
The assumptions for the geometric model are as follows:

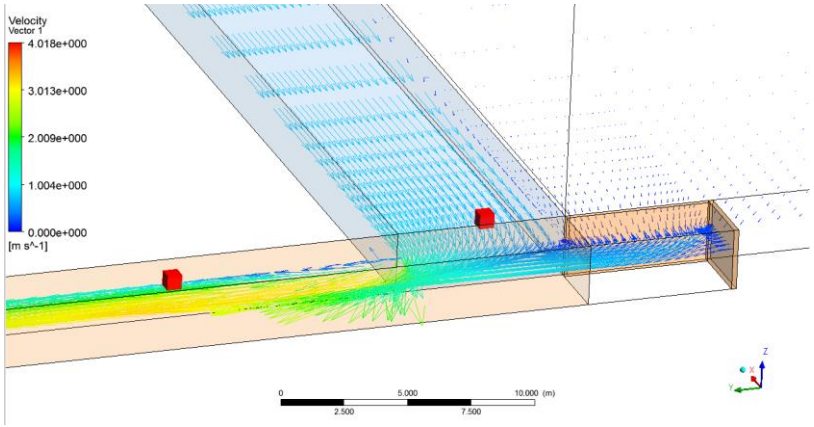
- The width of the longwall panel: 200 m
- The length of the longwall panel: 1000 m
- Longwall height: 2,5 m
- Roadway working's high: 2,5 m,



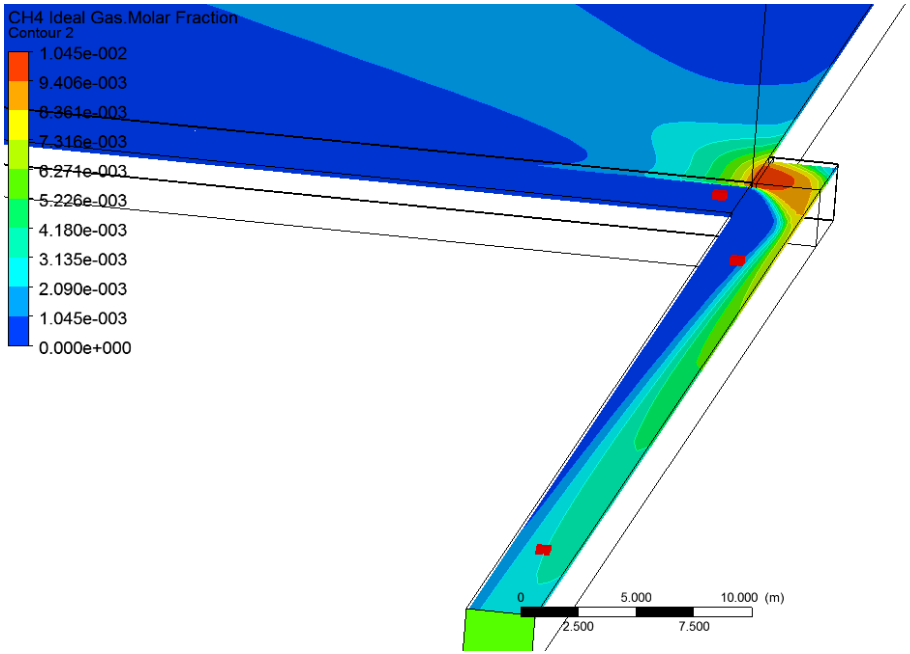
Velocity distribution simulation results in the environment of the ventilated longwall in „U" type system with the locations of the methanometry sensors

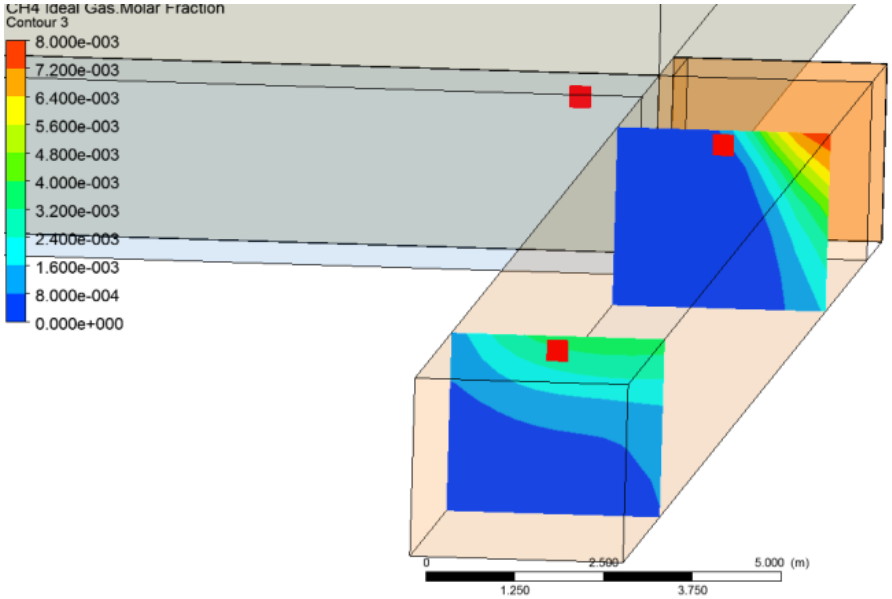






The methane concentration simulation results in the environment of the longwall outlet ventilated in „U" type system with the locations of the methanometry sensors.





AVENTO

The following figures show the proposed location of the methane sensors in the area of intersection of the wall with ventilation gangways with the “U” type ventilation system along the body of coal using geometric models at the assumed conditions of gas ventilation system 3D and 2D graphical diagram of the intersection.

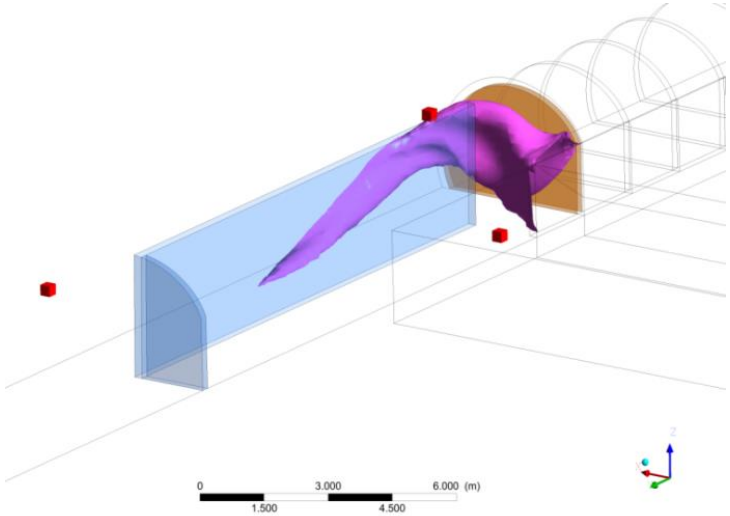
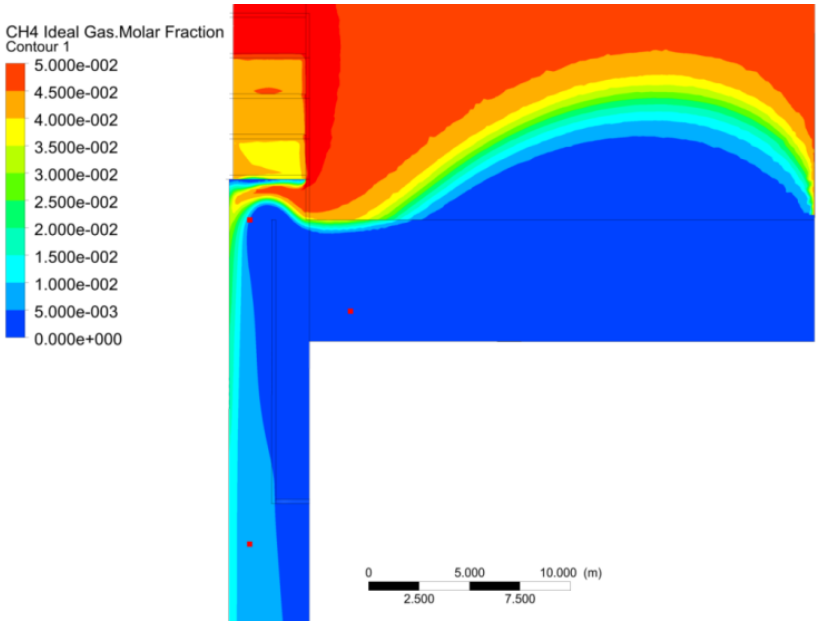


Figure shows the re-formation of the boundary surface of 3% methane concentration in the ventilation roadway (2m) liquidated by insulation dams, the conditions of ventilation and methane Q = 10 m^3/min,



Location of methane sensors at the intersection of longwall ventilated in the “U” type system with the ventilation roadway (imprinted boundary surface of 3% CH_4 methane concentration in the ventilation roadway liquidated by dams insulation, the conditions of ventilation and methane Q = 10m^3/min,

GasDrain

Research Fund for Coal and Steel (RFCS)

Developement of Improved Methane Drainage Technologies by Stimulating Coal Seams for Major Risks Prevention and Increased Coal Output

Primary Objective of proposed GASDRAIN project is to:

"investigate and research into borehole stimulation techniques and develop novel and improved methane drainage technologies, which will break the existing technological barriers and help increase safety and productivity in coal mines"

The GasDrain project aims to investigate the potential for the application of four different borehole stimulation techniques, namely:

1. hydraulic fracturing,
2. open or cased hole cavitation,
3. high pressure water jet slotting,
4. and the use of explosives to stimulate coal seams and the surrounding rock strata through laboratory experiments, numerical modelling and extensive field testing of the developed techniques at different mining conditions.

GasDrain - basic facts:

- **Realisation time: July 2015 – June 2018** (48 months)
- **Budget:** 3.8 mln €, including 1.1 mln € GIG
- **Partners:**
  - **GIG (Poland) – project coordinator (prof. Janusz Makówka)**
  - **JSW (Poland),**
  - **INIG-PIB (Poland),**
  - **Imperial College (UK), RWTH (Germany),**
  - **INERIS (France),**
  - **HUNOSA (Spain).**

GasDrain structure of the project (Work Packages (WP's)

WP0: Project Coordination and Reporting (GIG)

WP1: Characterisation of Coal Seams and Surrounding Rocks: Field Site Characterisation (RWTH)

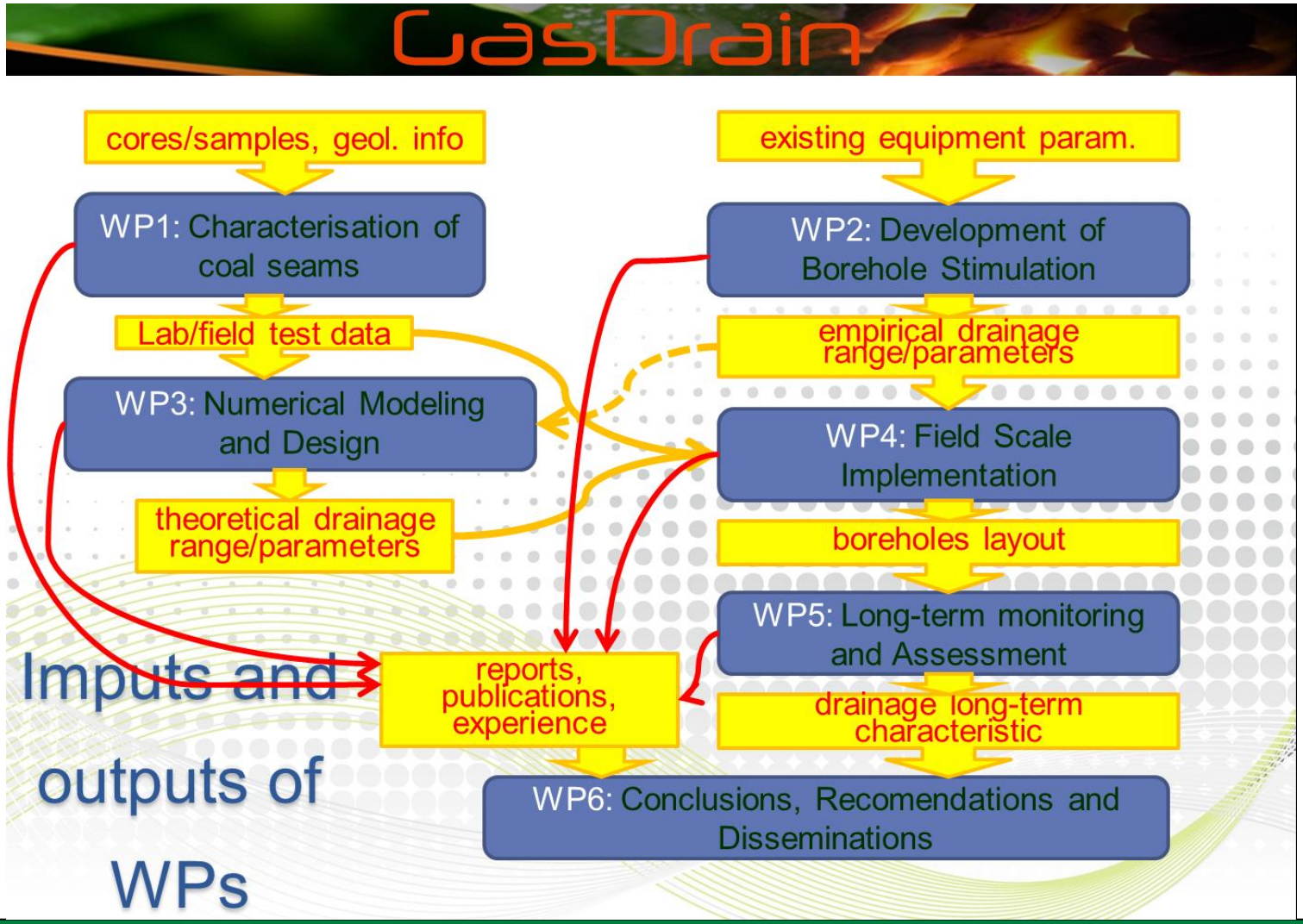
WP2: Development of Borehole Stimulation Technologies for Coal and Rock Formations (GIG)

WP3: Numerical Modelling and Design of Field Scale Stimulated Methane Drainage Processes (Imperial College, INIG)

WP4: Field Scale Implementation of Improved Methane Drainage Systems at Mine Sites (JSW SA)

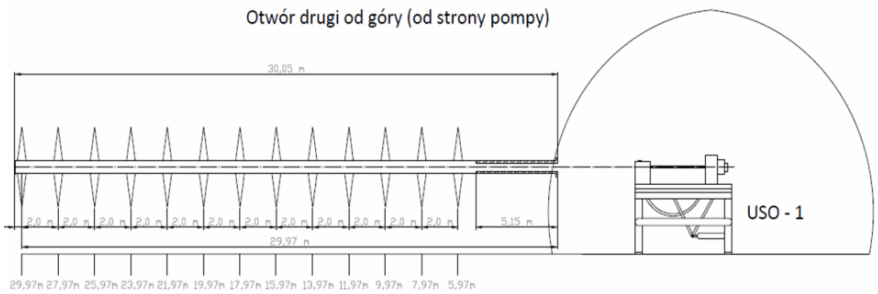
WP5: Long-term Monitoring and Assessment of Improved Methane Drainage Efficiency (AITEMIN)

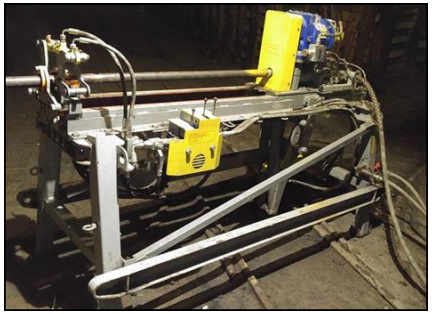
WP6: Conclusions, Recommendations and Dissemination (INERIS)

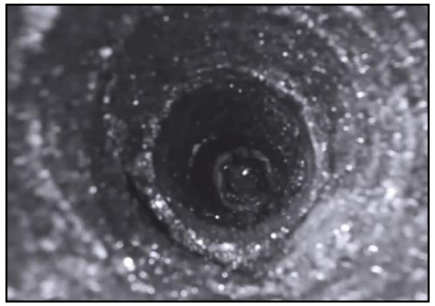

GasDrain
cores/samples, geol. info
existing equipment param.
WP1: Characterisation of coal seams
WP2: Development of Borehole Stimulation
Lab/field test data
empirical drainage range/parameters
WP3: Numerical Modeling and Design
WP4: Field Scale Implementation
theoretical drainage range/parameters
boreholes layout
WP5: Long-term monitoring and Assessment
reports, publications, experience
drainage long-term characteristic
WP6: Conclusions, Recomendations and Disseminations
Imputs and outputs of WPs

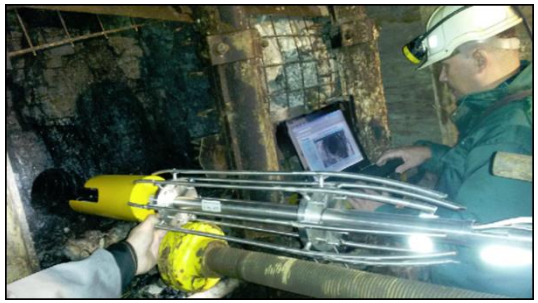
GasDrain

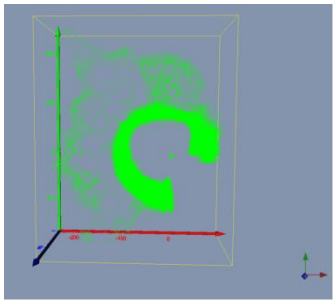
Examples of in situ tests performed in Experimental Mine „Barbara”











EXPRO

Prediction and Mitigation of Methane Explosions Effects for Improved Protection of Mine Infrastructure and Critical Equipment

Research Fund for Coal and Steel (RFCS)

EXPRO - basic facts:

- Realisation time: July 2015 – December 2017 (42 months)
- Total Budget: 2,402,465 €uros
- Coordinator: Central Mining Institute, prof. Krzysztof Cybulski
- Consortium:

GIG

EXPRO Project overview

The main aim of the EXPRO project is to develop tools and means that can help to adopt measures for mitigating the damages of methane explosions in the mine infrastructure and particularly in critical equipment

The project includes research work in the following areas:

- Obtaining a better understanding of the mechanical and thermal effects caused by methane explosions, by developing numerical models of explosions in different mine geometries and conditions, which will be validated with real scale explosion tests,

- Developing innovative air pressure monitoring systems specifically designed to record data that could serve for the purposes in the investigation after the occurrence of an explosion, and in particular for the determination of the ignition point.

EXPRO project summary

EXPRO project partners were focused on the realization of WP1,WP2 and WP3 referring to the following activities:

WP1 - Project coordination:

- management and coordination activities,
- organization of project meetings.

WP2 - Development and calibration of explosion numerical models:

- implementation of laminar burning velocity models,
- series of tests to verify the models,
- simulation of gas distribution in large volume (400 m gallery).

WP3 - Development of fast air pressure monitoring system:

- development of a modified sensor with a high response time,
- finalizing the ATEX certification process,
- completion of the software development,
- installation and testing of the system at the “Halemba” mine and during explosion tests at Barbara mine.

WP 2 Development and calibration of explosion numerical models

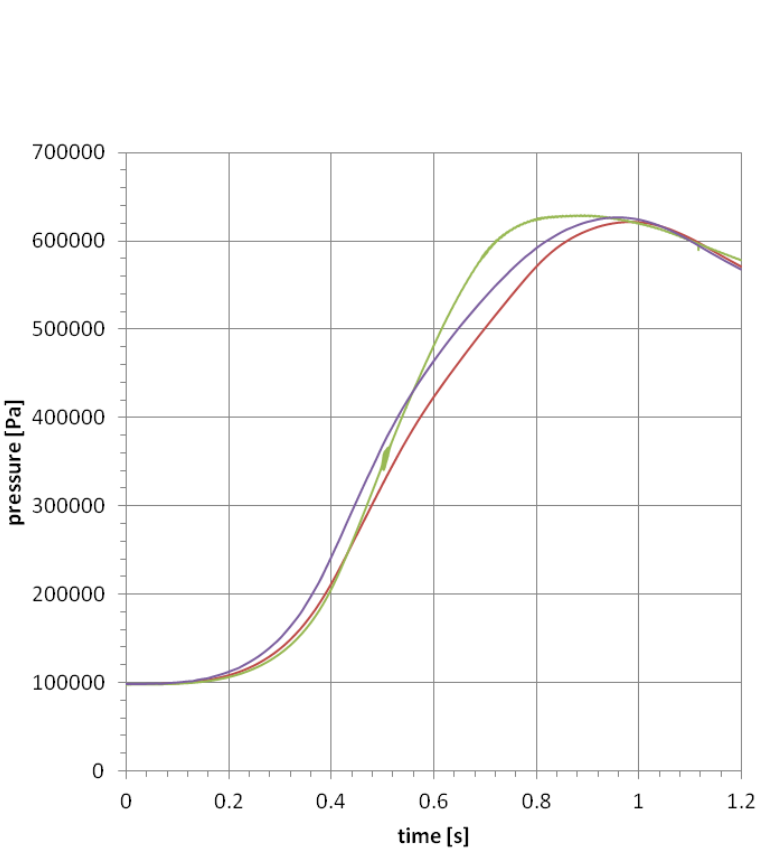
Task 2.2: Development of numerical models (led by GIG, AITEMIN, INERIS)

- **Adjustments in combustion models for the following:**
  - 20 dm^3 sphere,
  - 5 m^3 chamber (comparison Gulder model and SCOPE model)
  - 24 m tube for different diameters (150, 250 mm) and shapes (straight, bends)

- **Modeling of gas mixture distribution during real scale tests conditions for:**
  - slow methane occurrence in the working,
  - rapid release of a big methane volume.

- **Modeling of combustion development in real scale tests conditions for:**
  - flame propagation
  - pressure development
  - ignition time
  - temperature

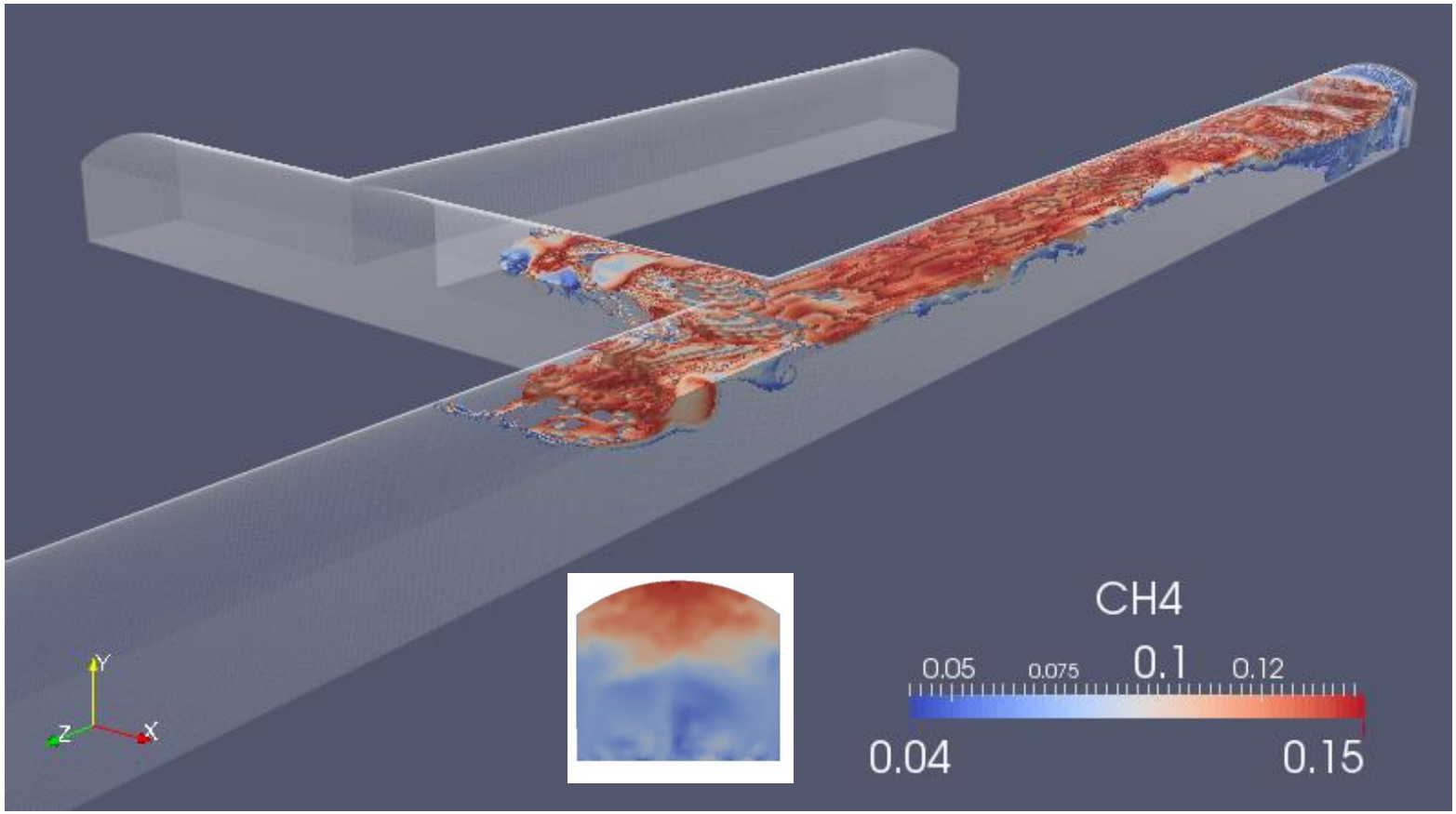
Comparison of pressure in time for tested models (5m^3 chamber)



5m^3 chamber test

GIG

EXPRO modeling of methane distribution for real scale tests conditions (400m gallery)



GIG

WP 2 Development and calibration of explosion numerical models

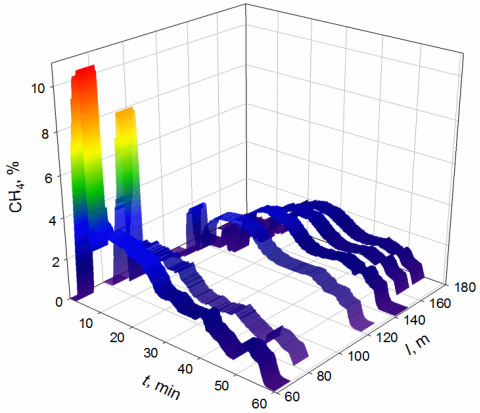
Task 2.3: Real scale tests (led by AITEMIN & FSB, INERIS, GIG, EMAG)

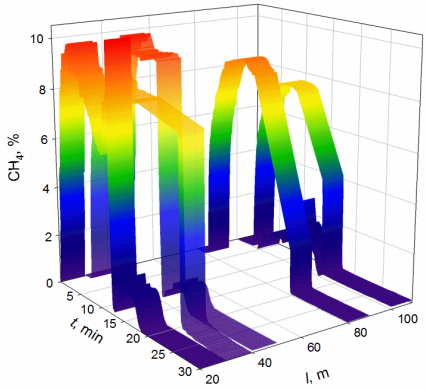
- **9 tests in the 400 m gallery at Experimental Mine Barbara with two ways in methane distribution applied**:
  - directly from the set of bottles, (slow methane occurrence),
  - using special PCV sleeve (rapid release of a big methane volume).

- **20 tests in the gallery in different configurations at FSB facility**:
  - small scale tests,
  - full gallery tests.

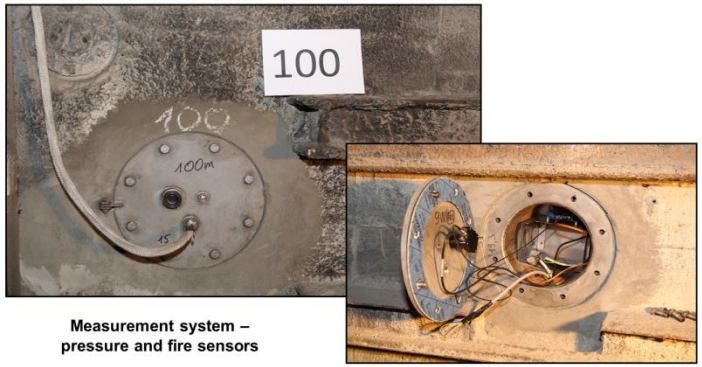
- **Series of tests covering a wide range of set-ups by INERIS:**
  - tube diameter (150, 250 mm),
  - tube inner roughness (plastic, steel),
  - shape of the pipework,

Real scale tests conditions: 400 m gallery, GIG Experimental Mine Barbara)





Methane dispersion in 400 m gallery under different conditions

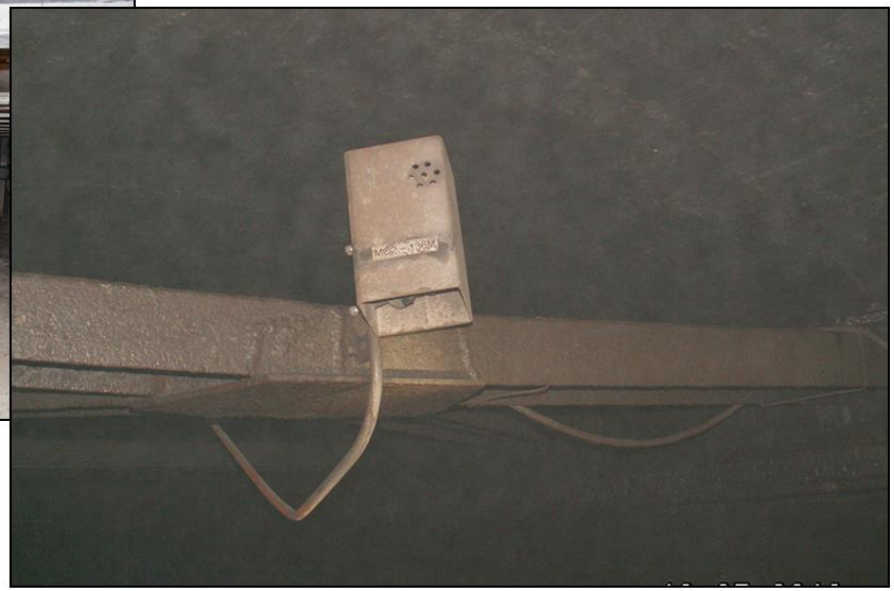


Measurement system – methane sensor

EXPRO Visual results obtained

Short Video

before



after

Equipment before and after experiments

MAPROC (Monitoring, Assessment, Prevention and Mitigation of Rock Burst and Gas Outburst Hazards in Coal Mines),

The main objectives of **MapROC** are to:

- develop and field test rock burst/outburst prevention techniques based on the use of large diameter boreholes with alternative stress and gas pressure relief techniques;
- formulate a methodology to couple the near-real time processing of monitored microseismic data with Artificial Neural Networks and Fractal Dimension analysis to develop a short-term prediction method for rock bursts/outbursts;
- demonstrate the use of this prediction method as a tool for early risk assessment, prevention, and mitigation of these hazards;
- numerically model the application stress relief, stress control and protective mining options;
- develop and validate a generic risk assessment methodology for rock bursts/outbursts.

MapROC project partners:

*The participation of **seven** partners from **five** different countries with important coal mining industries, enable to cover a variety of mining conditions across Europe.*
The consortium includes a balanced participation of industry, research institutions and universities, thus allowing both laboratory and mine tests.

AITEMIN is a non-for-profit independent research organization based in Madrid, Spain;

CM-Velenje - Premogovnik Velenje D.D., Slovenja

GIG - **C**entral **M**ining **I**nstitute of Katowice, Poland

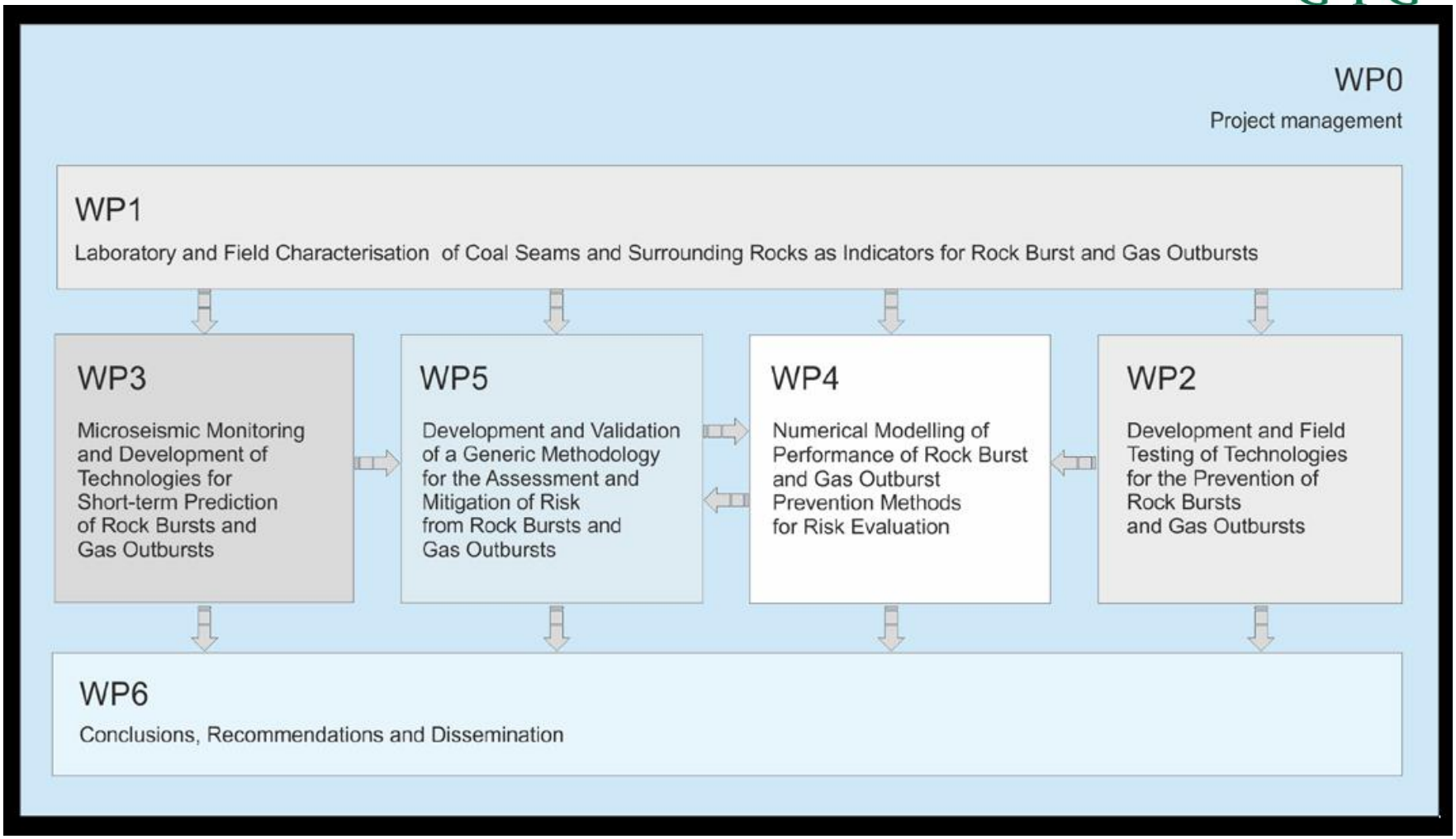
HVL - **H**ullera **V**asco-**L**eonesa, Spain

IMPERIAL - **Imperial College of Science Technology and Medicine (U.K.)**

JSW SA - Jastrzebska Spolka Weglowa SA, Poland

RWTH Aachen University, Germany

MapRoc


WP0
Project management
WP1
Laboratory and Field Characterisation of Coal Seams and Surrounding Rocks as Indicators for Rock Burst and Gas Outbursts
WP3
Microseismic Monitoring and Development of Technologies for Short-term Prediction of Rock Bursts and Gas Outbursts
WP5
Development and Validation of a Generic Methodology for the Assessment and Mitigation of Risk from Rock Bursts and Gas Outbursts
WP4
Numerical Modelling of Performance of Rock Burst and Gas Outburst Prevention Methods for Risk Evaluation
WP2
Development and Field Testing of Technologies for the Prevention of Rock Bursts and Gas Outbursts
WP6
Conclusions, Recommendations and Dissemination

Work Package 1 aims at carrying out a limited number of laboratory experiments to characterise some partner mine and other European coals for their gas release dynamics to fill in missing data which may not have been collected in previous projects. Additional laboratory research will involve upgrading of the large diameter triaxial cell to enable acoustic measurements under stress and gas flow conditions. The prevailing in situ stress state and strain conditions around working Longwall and Longwall Top Coal Caving and Sub-Level caving coal faces at JSW, CM-VELENJE and HVL will be assessed through empirical and numerical methods.

Work Package 2 will carry out field experiments using large diameter boreholes for stress and gas pressure relief, implementing either blasting or slot cutting or high pressure water injection depending on the mine and type of coal that exists and aim at determining their effectiveness in developing the desired stress and gas pressure relief around the workings. As JSW will carry out similar experiments in small diameter gas drainage boreholes, most experiments will not be repeated there and the equipment and blasting methods developed in GasDRAIN will be available for use by the other two industrial partners who are not involved in GasDRAIN. JSW will help in the use of the equipment at CM-VELENJE and HVL as necessary. AITEMIN will investigate the potential use of Measurement While Drilling techniques in order to take advantage of routine drilling operations performed, either for pressure relief or for production (blasting), for acquiring data that is helpful to characterise the rock or coal mass from the point of view of outburst risk.

In **Work Package 3,** GIG will aim at developing and validating a real time microseismic monitoring and data processing routines in order to provide near-real time (maximum one week intervals) seismic source energy, location and bent-ray tomograms to IMPERIAL for further analysis and development of Artificial Neural Network and Fractal Dimension based advance and near-real-time rock burst and gas outburst prediction models. The models will be trained and calibrated using the early period monitoring data from the mines, and will be validated by carrying out predictions during the second half of the project.

Work Package 4 will utilise the results of Work Packages 1, 2 and 3 and build numerical models to analyse the effectiveness of the large diameter borehole based stress and gas pressure relief methods for different mine layouts representative of those used at the partner mines and other European mines. Data generated through the field trials of different borehole techniques in WP 2 will be used to establish an understanding of the processes involved stress and gas pressure relief to prevent rock bursts and gas outbursts. Furthermore, WP4 will numerically assess two other preventative methods, namely stress relief mining and protective mining involving sacrificial drivages, pillars and under/over mining methods as could be applied in different coal mining methods (LW, LTCC, SLC).

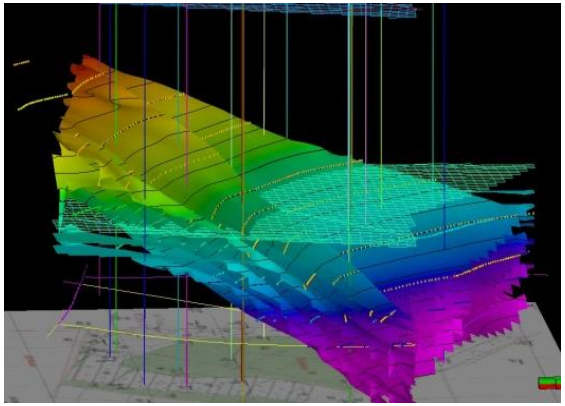
Work Package 5 aims at developing and validating a generic risk assessment method for rock bursts and gas outburst. The site specific methodology developed by AITEMIN for HVL in CoGasOUT will be extended through collaboration with JSW and CM-VELENJE and utilise production and field measured data to generalise the methodology. The model will be validated through application to the conditions of the three industrial partners. This WP will also combine the numerical models of WP4 and the previously developed gas outburst models to carry out a probabilistic assessment of risk in different mining conditions and layouts, and analyse sensitivity to field parameters. Research will consider and evaluate the factors which may affect the performance of developed techniques in different coal fields and geological conditions and report these.

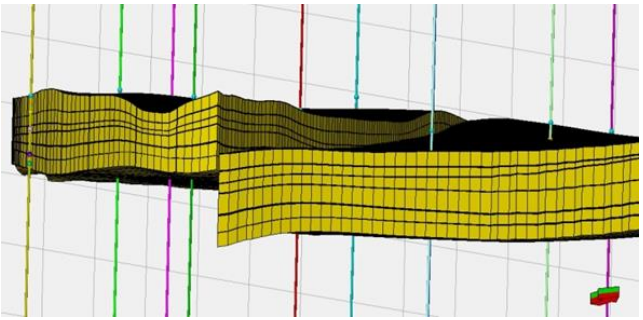
Work Package 6 focuses on the conclusions and dissemination of research findings. Partners will compile the background state of the art knowledge in rock bursts and gas outbursts together with the MapROC field and numerical modelling practice and experience gained from the research outcomes. In particular, the short term prediction models developed will be documented and demonstrated to the industry. It is planned to organise a project Workshop to disseminate this knowledge to a wide audience within the European coal mining community. As a second objective, and upon completion of all the project tasks, a project “lessons learnt and recommendations document” will also be compiled and issued to assist industrial stakeholders and the scientific community towards achieving the general objectives of predicting, preventing and mitigating rock bursts and gas outbursts in coal mines.

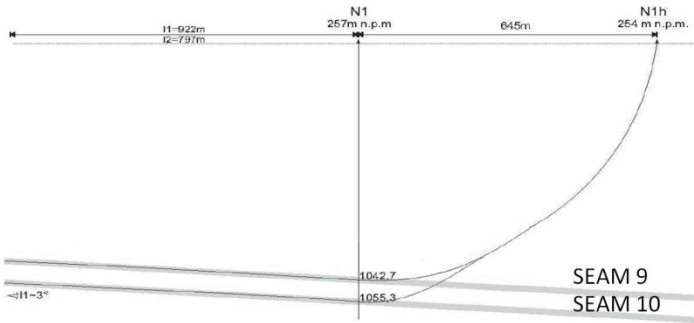
EPA2 grant

A FIRST FEASIBILITY STUDY FOR COST EFFECTIVE METHANE DEGASSING AND CAPTURE AHEAD OF MINING OPERATIONS TO REDUCE METHANE EMISSIONS IN POLAND DURING MINING (PAWLOWICE 1 COAL FIELD, UPPER SILESIA)

Budget: 340,000 USD, funded by US EPA grant.
Coordinator: Central Mining Institute of Katowice, Ph.D.Eng Jacek Skiba
Duration: 10.07.2009 – 10.07.2013



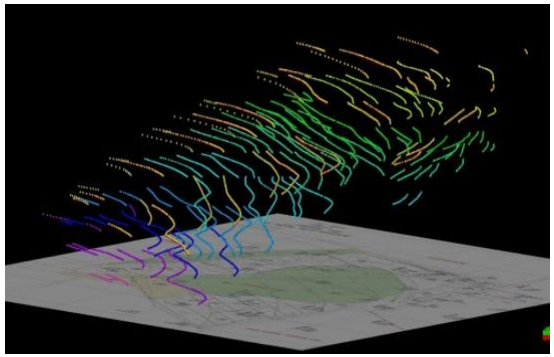


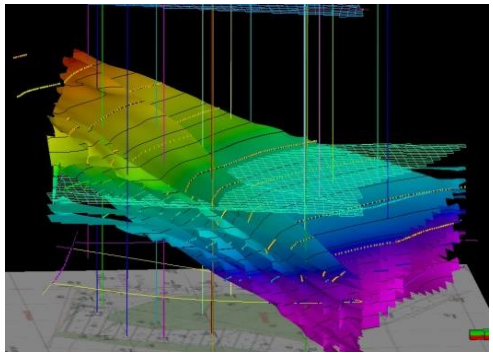


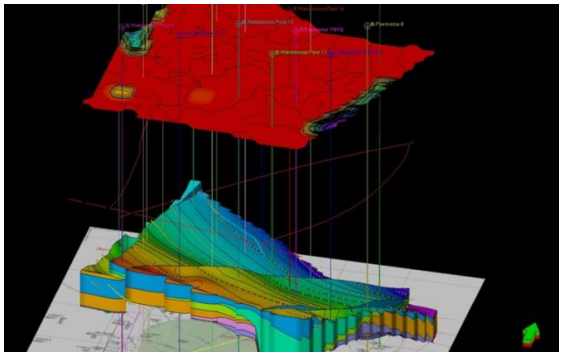
EPA2 grant

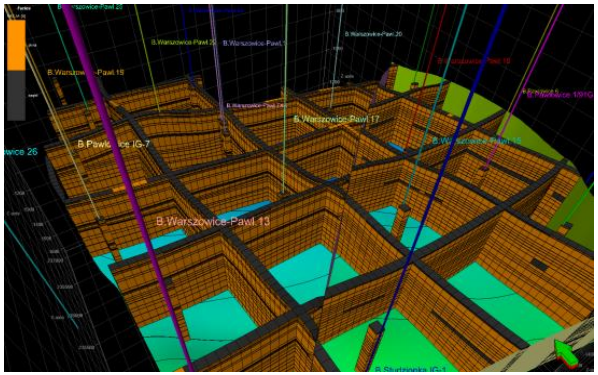
Technical feasibility	T1	Identification of coal seams to be the target of mining operations
	T2	Methane predictions for the planned mining operations
	T3	Design of CBM production and degassing system using surface-bored wells which include:
	T3.1	*data collection*
	T3.2	*determination of coal reservoir parameters*
	T3.3	*determination of coal seam continuity (depositional characteristics, structural features);*
	T3.4	*selection of appropriate drilling technology based on the US CBM experience;*
	T3.5	*preparation of CBM drilling, completion and production design;*
	T3.6	*determination of well locations and well spacing;*
	T3.7	*determination of production volumes using reservoir simulator*
	T3.8	*determination of methane drainage effectiveness using reservoir modeling techniques;*
	T3.9	*planning of produced water disposal*
	T4	Estimation of methane emission reductions
Economic analysis	T5	Estimates of the CBM production implementation cost
	T6	Review of methane end-use strategies
	T7	Calculating of net revenues and estimating of the CBM production project lifetime
	T8	Development of an economic model and calculating NPV and IRR
	T9	Converting estimated methane emission reductions to carbon credits
	T10	Estimates of possible cost savings for the Pniowek coal
	T11	Final economic analysis
	T12	Conclusions and recommendations

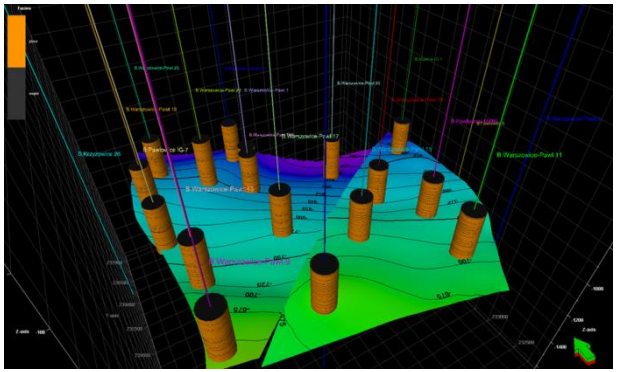
EPA2 grant

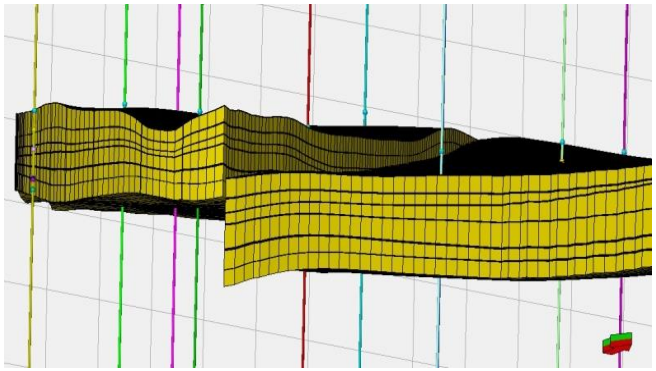




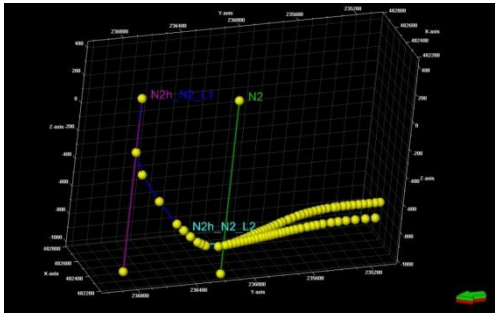


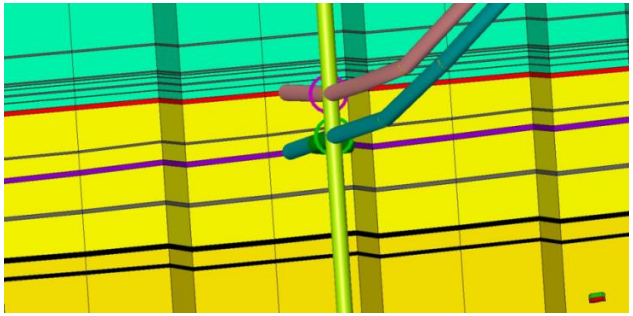


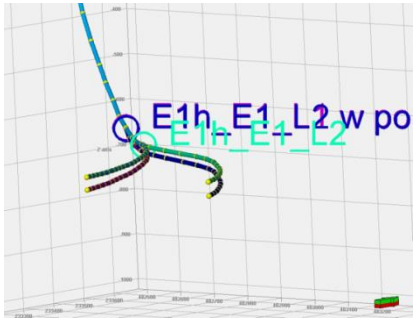


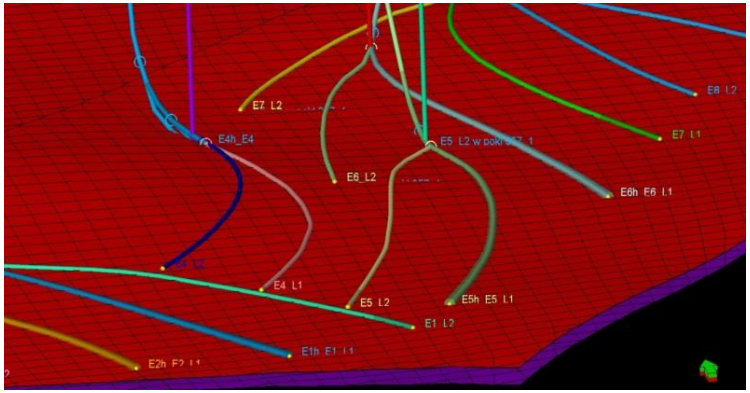


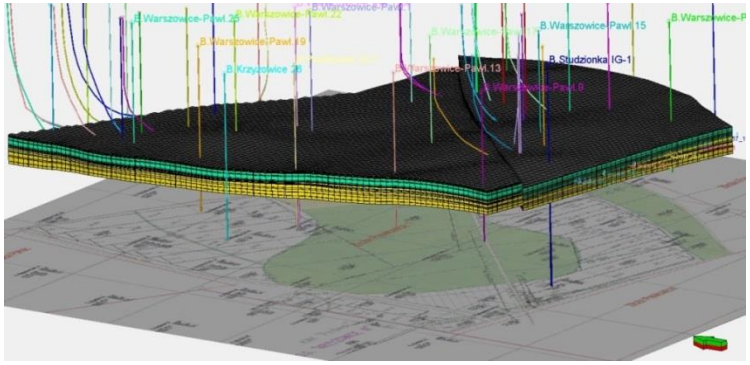
EPA2 grant

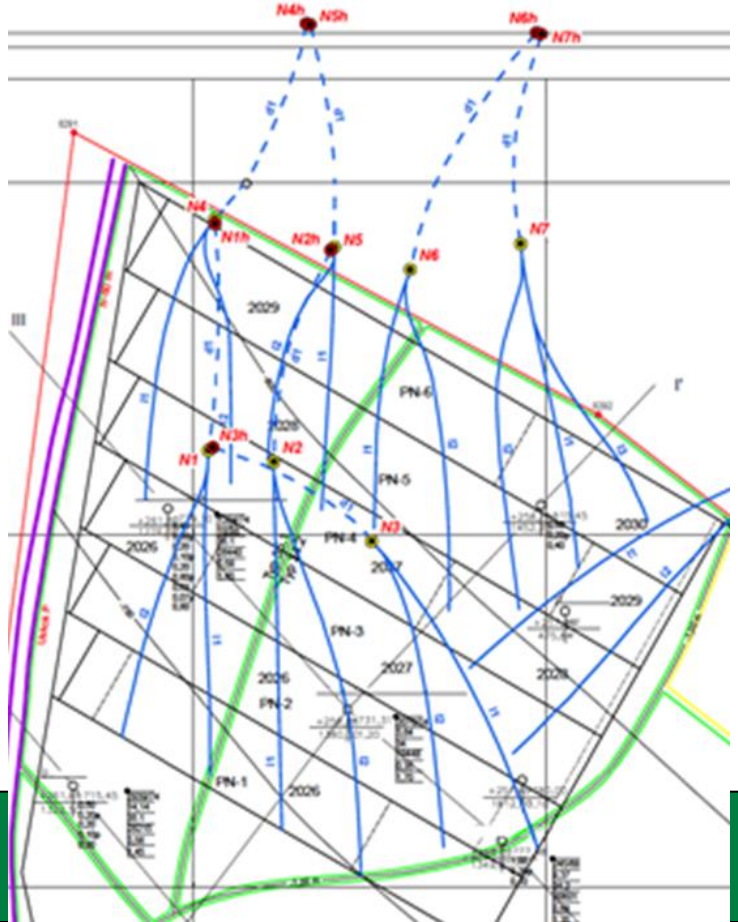

N2h_N2_L1
N2
N2h_N2_L2




E1h_E1_L2 w po
E1h_E1_L2


E7_L2
E4h_E4
E5_L2 w pokł.E7_1
E8_L2
E7_L1
E6_L2
E6h_E6_L1
E4_L1
E5_L2
E5h_E5_L1
E1_L2
E1h_E1_L1
E2h_E2_L1


B.Warszowice-Pawł.15
B.Studzionka IG-1
B.Krzyżowice 28


N4h
N5h
N6h
N7h
N4
N1h
N2h
N5
N6
N7
N1
N3h
N2
N3
PN-6
PN-5
PN-4
PN-3
PN-2
PN-1
2029
2026
2027
2028
2030

Analysis of methane drainage from directional wells was made based on **the results of numerical calculations for the period of 5 years.**

Symulations were performed using AnsysCFX software - group CFD (**Computational Fluid Dynamics) software using finite volume method.**

For the calculations the **izothermal process of drainage was assumed.**

The temperature of gas was assumed the same as the rock mass t=41 ^{o}C and non-stationary conditions for methane filtration and desorption from the coal beds.

Coal was treated as dry medium (without water) with following parameters :
- **Porosity γ = 5%,**
- **Permeability K = 2 mD**.

Assumed **methane content of the coal seam:**
- **SEAM 9 = 12.75 m^3/t_{daf},**
- **SEAM 10 = 13.70 m^3/t_{daf}.**

The sorption kinetics was assumed k=0.0001 and bed pressure from Langmuira isotherm, which was determined during borehole tests.

Conclusions

1. All of above mentioned R&D Projects focus on mitigating CMM hazard and its effective utilisation

2. Most of above mentioned R&D Projects were/are cofinanced by Research Fund for Coal and Steel (60%), remaining 40% by individual project partners countries

3. Very high factor of implementation the R&D results in mining sector !

4. RFCS activities are effective European Commission support of not only CMM related R&D projects but also projects focused on „accompanying measures”.

GIG

Thank you for your attention