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Coal Mine Gas

CMM End-uses: Applications for Mongolian Conditions

Clean energy and climate change mitigation globally

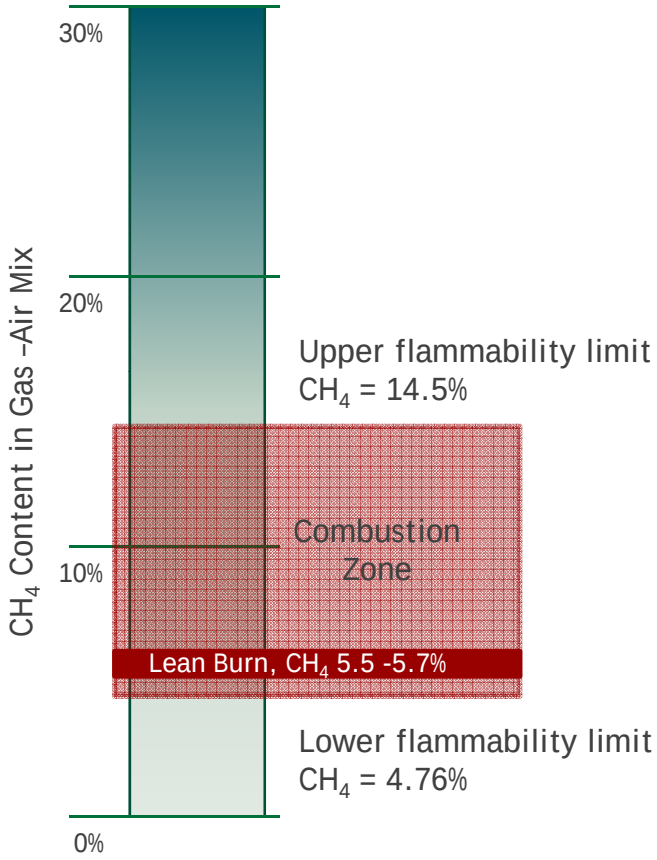
August 2010 | Green Gas (Beijing) Clean Energy Technology. Ltd.

Coal Mine Gas – What is it?

- Coal Bed Methane (CBM) is a byproduct produced during the formation of hard coal from organic residue. It is contained in the coal seams and in small amounts in the surrounding rocks.
- Typical composure of CSM in undisturbed geological formations is:
  - Methane 90% - 95%
  - Ethane and Long Chain Hydrocarbons (LCH) 0.1% - 3%
  - Carbon dioxide 2% - 4%
  - Nitrogen 0% - 5%
  - Hydrogen, Helium and Hydrogen Sulphide Trace Elements
- CSM is released to the environment due to disturbance of the geological structure by
  - Underground mining related activities → Coal Mine Gas (CMG)
  - Gas Exploration → Virgin Coal Bed Methane (VCBM)

Coal Mine Gas – Why dealing with it?

- Coal Mine Gas (CMG) is CBM that is released into the environment due to mining related activities. During this release process the Gas is diluted with ambient air and changes composition.
- A mixture of CMG and ambient air poses risks and is a liability to the mine operator
  - Explosion risk because of Methane – Oxygen mix
  - Health risk because of limited Oxygen in the working areas.
- In order to have a safe and commercially successful mining operation CMG needs to be handled and taken care of.
  - Proactive degas coal seams prior and during mining
  - Monitor mine atmosphere and provide safe conditions through ventilation



Methane Flammability Limits
Norm Conditions

Coal Mine Gas – Typical Composition

- Typical compositions of different CMGs

	CMM	AMM	VAM
Methane	5% - 75%	20% - 50%	0.1% -1.2%
Ethane and LCH	0.1% - 3%	0.1% - 3%	NA
Carbon Dioxide	0.1% - 3%	0.1% - 5%	NA
Nitrogen	10% -60%	10% - 60%	ca. 79%
Oxygen	1% - 15%	0.5% - 15%	ca. 20%
Hydrogen	Trace Element	Trace Element	NA
Helium	Trace Element	Trace Element	NA
Hydrogen Sulphide	Trace Element	Trace Element	NA

- Coal Mine Methane (CMM) and Abandoned Mine Methane (AMM) are gases that are combustible and therefore an energy source
- Ventilation Air Methane (VAM) is basically ambient air with a small amount of Methane.

Coal Mine Gas – utilise, why?

- Reasons to utilise CMG are:
  - We have to handle CMG anyway for safe Mining operations
  - Because Methane is a major component of CMM and AMM those gases are energy resources and can be reliable used in Lean Burn applications such as IC Engines
  - Escaped Methane from coal mines is a major contributor to global warming. The global warming potential of Methane is 21 times higher than Carbon dioxide.
  - It is a local energy source that can provide distributed power. Therefore transportation losses are minimized
  - Due to close proximity to the mine Combined Heat and Power (CHP) solutions can be developed leading to overall energy utilisation of up to 85%

→ Utilisation of CMM and AMM is the obvious choice to deal with a gas that is a proofed energy resource and has to be gathered and handled anyway.

→ VAM is major contributor to global warming. Effects of VAM to the environment should be limited and the energy used.

Coal Mine Gas – Utilisation, how?

- Utilisation of CMG has to follow three basic rules:
  - Utilisation needs to be safe

    The mining operation can not be compromised. Therefore management of the gas drainage and gathering system is important.
  - Utilisation needs to be reliable

    Optimized gas production and gas treatment lead to reliable operation of the utilisation plant. Operations management of the plant is key to reliable output.
  - Utilisation needs to be cost competitive

    Main driver for cost are operations cost. Therefore operations management is key for a cost competitive utilisation.

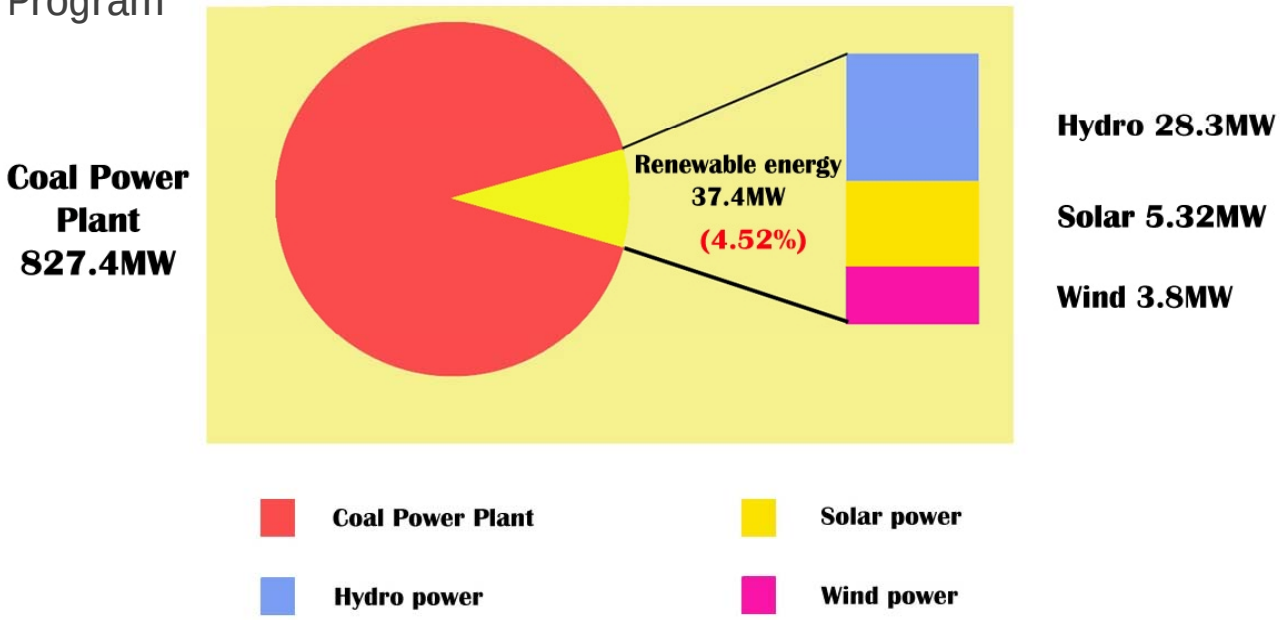
➡ Experience is key for successful Coal Mine Gas utilisation.

Coal Mine Gas – Utilisation

- There are various technologies to utilise CMM and AMM
  - Gas to Energy
  - Direct Use
  - Gas to Pipeline
  - Liquefied Natural Gas (LNG)
- There are various technologies to utilise VAM but the huge volumes set limits to technologies
  - Thermal or Catalytic oxidation
  - Substitute combustion air in boilers, gas turbines or engines
- Key decision is to choose the most economical technology based on
  - Gas quality and quantity
  - Physical location
  - Market location

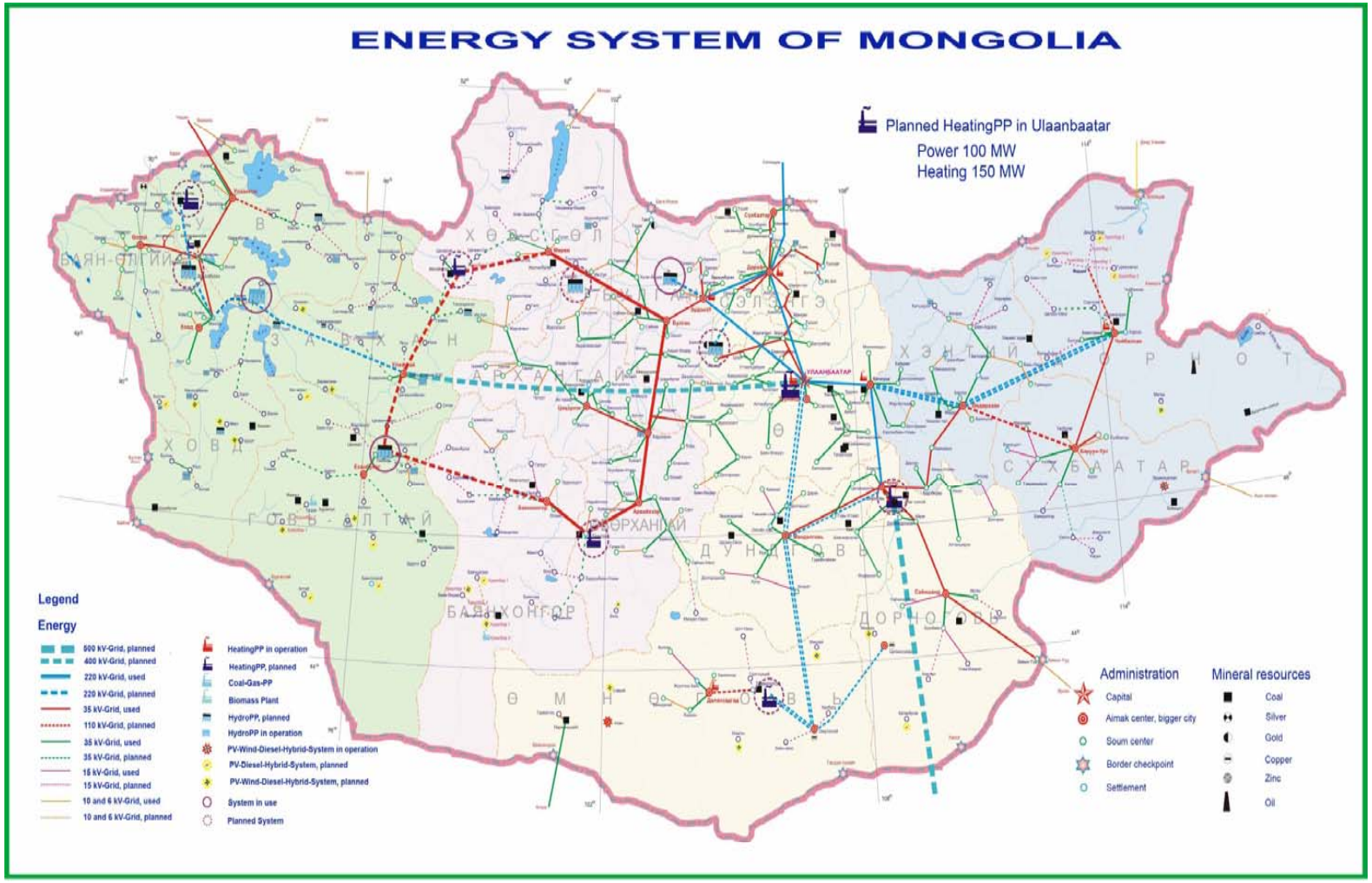
Coal Mine Gas – Mongolia

- Large country with small population
- Extreme Geographical and climate conditions
- Energy Production and consumption depends on coal
- Open pit mining
- No Natural Gas Infrastructure
- Electrical Distribution system mainly arround Ulaanbaatar but in development
- Renewable Energy Program



Source: Ministry of Mineral Resources and Energy, Mongolia

Coal Mine Gas – Energy System of Mongolia



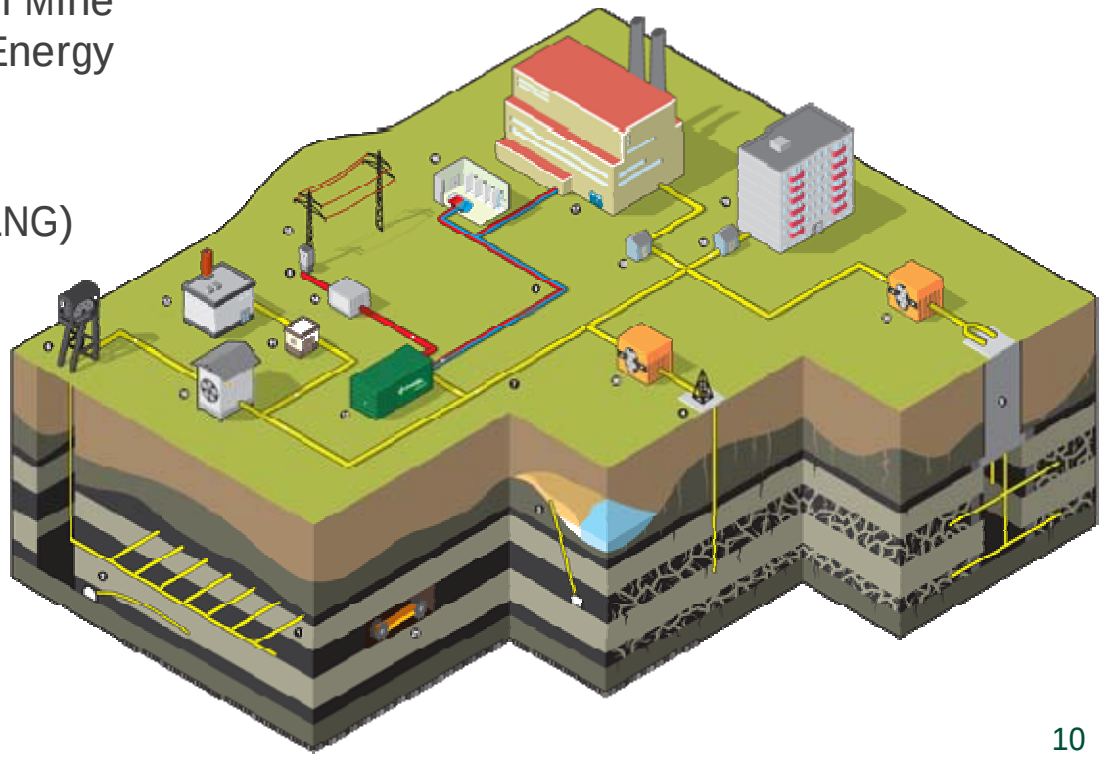
Source: Ministry of Mineral Resources and Energy, Mongolia

Coal Mine Gas – Utilisation

- Because of the existing Infrastructure Gas to Pipeline is not an option
- Because of the mining operation VAM is not available
- Most CMG will come from degassing prior to open pit mining

➡ Most suitable technologies for CMG utilisation in Mongolia are:

- Gas to Energy and use in Mine grid or export to Energy System
- Direct Use in Boilers
- Liquefied Natural Gas (LNG)



Coal Mine Gas - The Green Gas Approach

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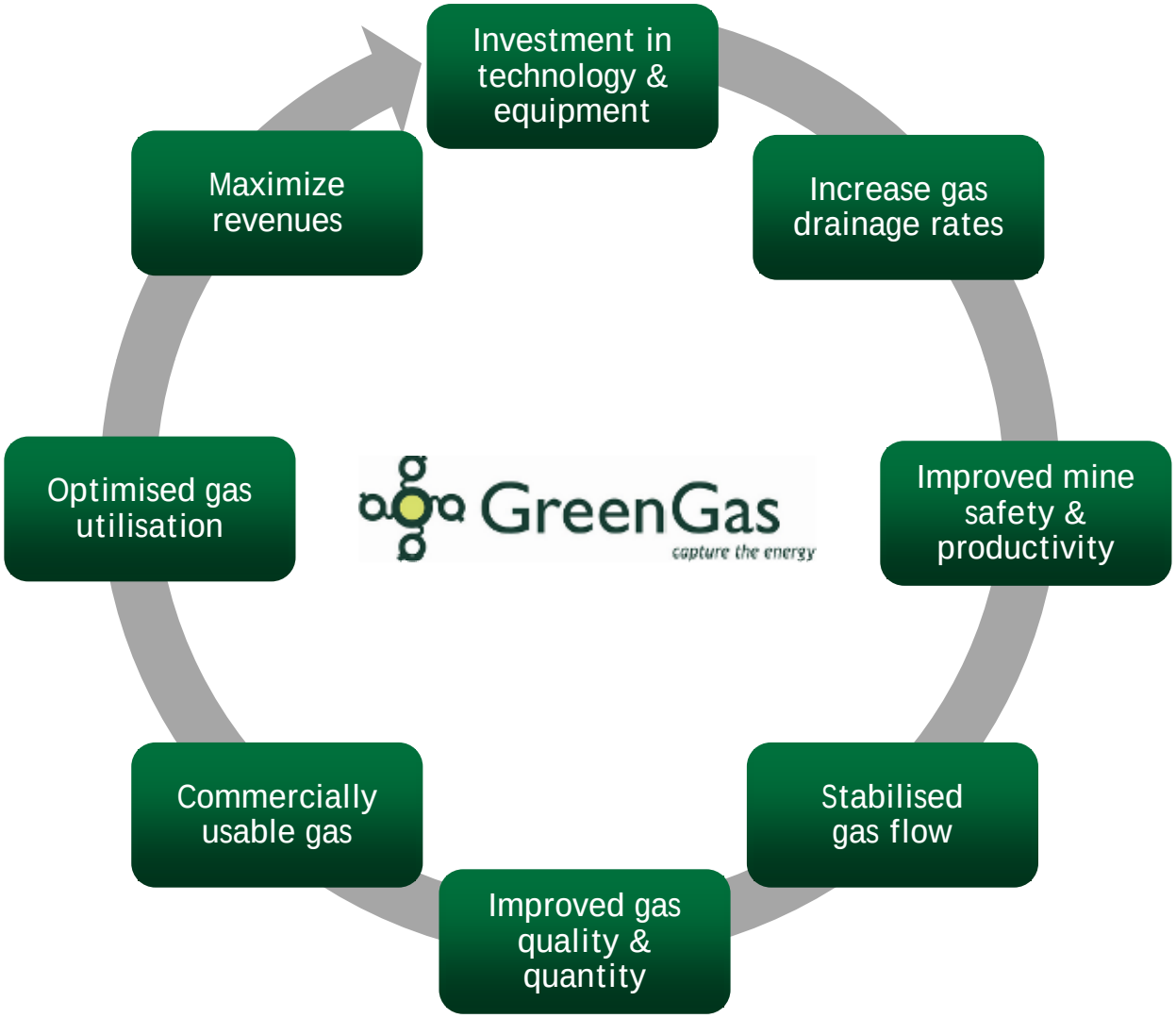
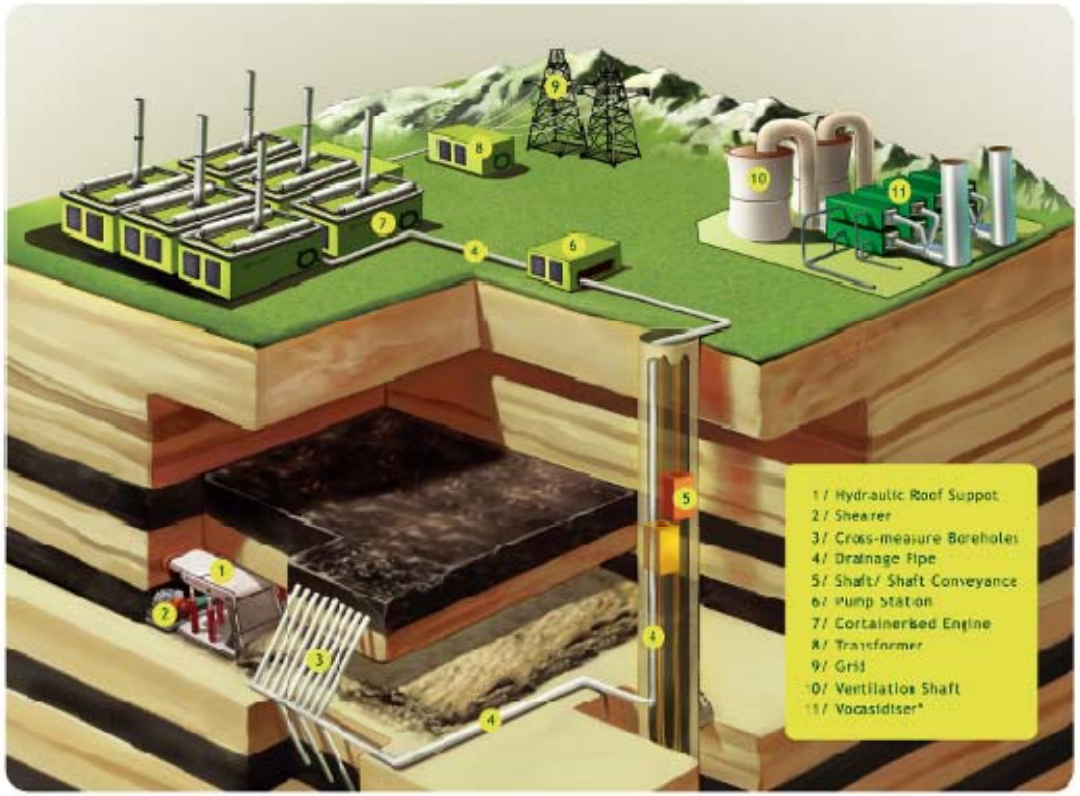


Coal Mine Gas – Subsurface Approach

- Study the mine — Collect data on geology, gas content of seams, mining methods, existing drainage.
- Predict outcomes — Evaluate impact of alternative technologies, including optimised existing drainage system
- Design drainage — Design optimum system for the local conditions
- Implementation — Assist procurement, installation, commissioning
  - Equipment upgrades
  - Adjusted working practices
  - Changes in working behaviour
- Training — Familiarisation with new techniques & equipment
- Monitor — Ensure optimum performance, adjust parameters

Coal Mine Gas - Subsurface Approach

- Full subsurface gas resource assessment
- GGI as drainage improvements include:
  - Equipment upgrades
  - Adjusted working practices
  - Changes in working behaviour
- Benefits of GGI approach:
  - Increased mine safety
  - Increased coal production
  - Increase of gas quantity & quality
  - Decrease of required ventilation



Coal Mine Gas – Advantages of CMM to Energy

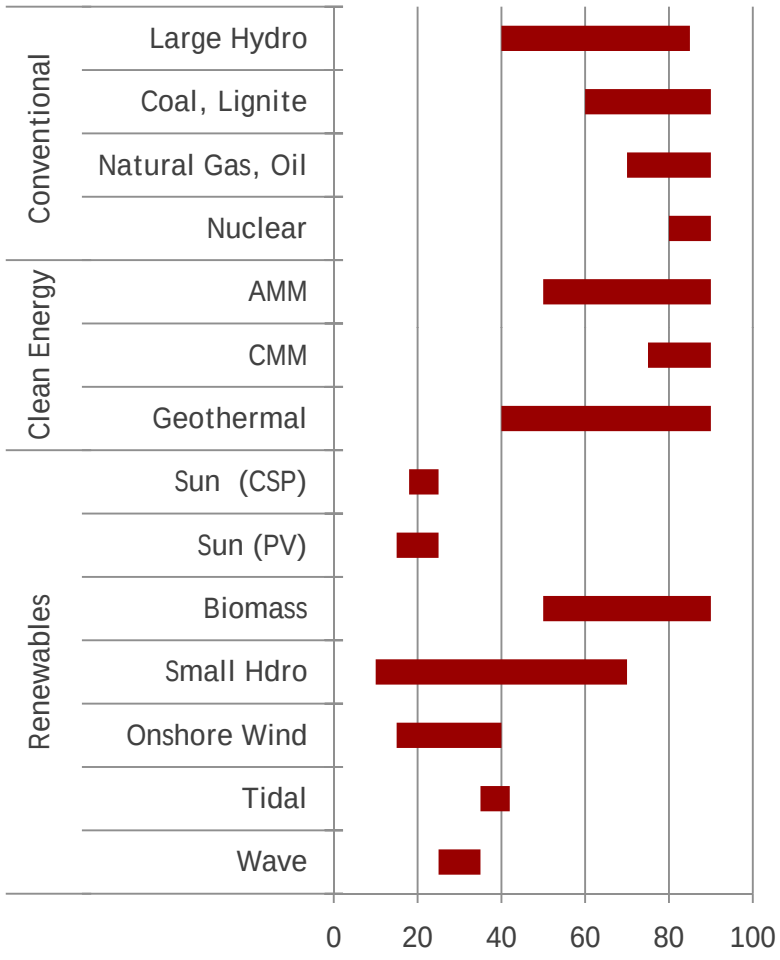
- Subject to gas quality and flow there are different suitable technologies for power generation
  - Reciprocating Internal Combustion Engine (IC Engine)
  - Turbine Engine
  - Steam Turbine
  - Fuel Cell
- IC Engines have become the prime mover of choice for conversion of low caloric methane based gases to energy. The reasons are:
  - Available in a wide range of unit size (100kW to 4,000kW)
  - Efficiency between 35% and 44%
  - Efficiency comparable stable operated in partial loads down to 70%
  - Easy to install
  - Low pressure gas system
  - Capacity factor up to 90%

→ CMM and AMM utilisation in IC Engines supplies environmental friendly base load energy

Coal Mine Gas – Characteristics of Technologies

	Capacity Factor	Resource	Applications	Comment
Wind Turbine	15% - 40%	Kinetic Energy of Wind	Electricity	Fluctuating Supply defined by resource
Sun (PV)	15% - 25%	Direct and Diffuse Sun Radiation	Electricity	Fluctuating Supply defined by resource
Sun (CSP)	18% - 30%	Direct Radiation tracking the Sun	Electricity and Heat	Fluctuating Supply defined by resource
Biomass	70% - 85%	Organic and Solid Residues and Wood	Electricity and Heat	Power on Demand, Storage, Base Load Power
Geothermal	40% - 90%	Slow Decay of Radioactive Particles in the Core of the Earth	Electricity and Heat	Power on Demand Base Load Power
Hydro	30% - 90%	Kinetic Energy and Static Pressure from Water	Electricity	Power on Demand, Storage, Base Load Power
CMM	75% - 90%	Mine Gas from active Underground mines	Electricity and Heat	Power on Demand Base Load Power
AMM	50% - 90%	Mine Gas from abandoned Underground mines	Electricity and Heat	Power on Demand, Bas Load Power
Natural Gas, Oil	20% - 90%	Fossil Fuels	Electricity and Heat	Power on Demand Base Load Power
Coal, Lignite	40% - 90%	Fossil Fuels	Electricity and Heat	Power on Demand Base Load Power
Nuclear	85% - 95%	Uranium	Electricity and Heat	Base Load Power

Coal Mine Gas – Reliable Clean Energy



Average Capacity Factors by Fuel(1)

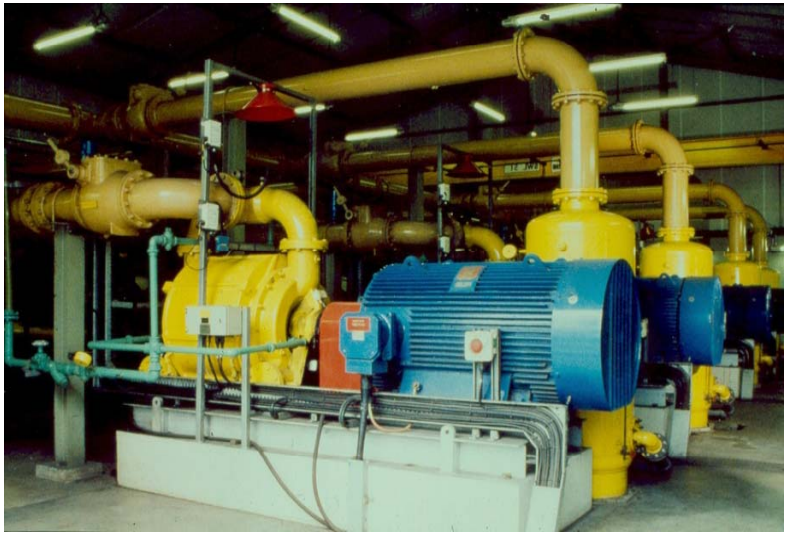
	[%]
Nuclear	90.5
CMM (IC Engine)(2)	82.6
Geothermal	71.5
Biomass	66.3
AMM (IC Engine)(2)	64.0
Coal (Steam Turbine)	63.1
Gas (Combined Cycle)	44.7
Hydro	29.4
Wind	27.8
Solar	23.5
Gas (Steam Turbine)	13.3
Oil (Steam Turbine)	7.4

(1) If not otherwise stated 2009 US Data, Source: NEI
(2) Green Gas International 2009 Data

Coal Mine Gas – Experience leading to success

Green Gas DPB Mine Gas Portfolio

- Based in Ostrava, Czech Republic
- Drainage and utilisation of CMM and AMM
- Methane Production: 100 million m^3/year
- Operation of >200 km pipeline system for optimized gas supply to enhance reliability
- Multiple utilisation solutions
  - 18 power plants with installed capacity of 22 MW_{el}. Waste heat is utilised for optimal use of energy
  - Gas distribution to industrial users for direct utilisation in boilers



Coal Mine Gas – Experience leading to success

Mine Gas GmbH Portfolio

- Based in the German Ruhr area Market leader in mine gas production from abandoned mines in Germany
- Joint Venture of Green Gas, Evionik and Lambda
- Utilisation of AMM
- Methane production: 123 million m^3/year
- 17 power plants with installed capacity of 77 MW_{el}. Waste heat is utilised if possible for optimal use of energy
- Green Gas is responsible for operations and maintenance management as well as dispatching

Coal Mine Gas – Treat the Gas

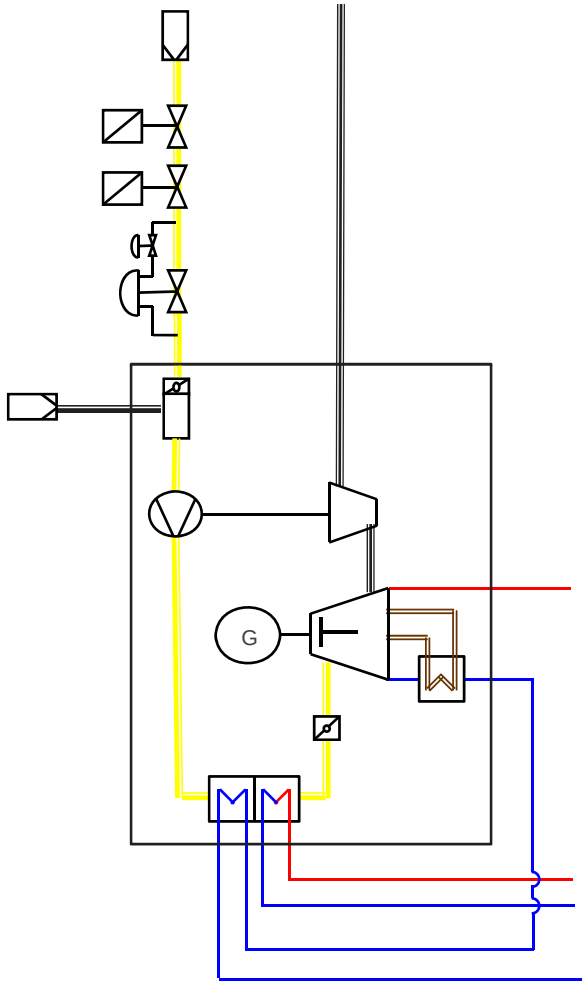
- Gas quality is crucial for engine lifetime and operating cost
- Gas supply needs to be
  - Stable
    - Flow
    - Sufficient pressure
    - Gas engines are not able to handle fast changes in either flow or pressure
  - Within reasonable quality
    - Below a relative humidity of 80% under any circumstances
    - Sulfur and other trace components need to be treated
  - Safe
    - Safety margins from flammability limits
- Stable gas supply ensured by own blower station (pressure) and buffer tank (flow)
- Quality ensured by dehydration (Humidity) and gas treatment (reduction of trace elements)
- Safety ensured by min. Methane content (25%) and fuel gas analyzer

Coal Mine Gas - Power Generation

- Experience with all types of IC engines
- Independent from engine manufacturer
- High availability thanks to international experience and local services.

Coal Mine Gas - Components of Power Module

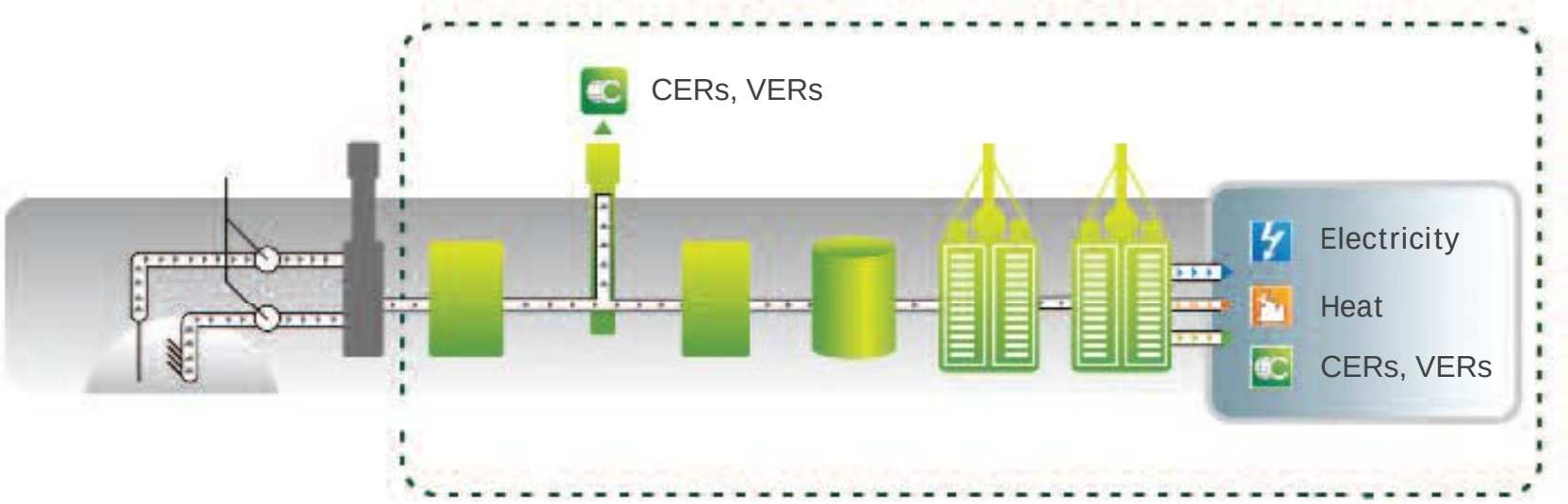
- Gas Train
- Engine
- Alternator
- Exhaust Gas System
- Hot Temperature Water Circuit
- Low Temperature Water Circuit
- Combustion Air System
- Cooling Air System
- Oil System
- Measurement Equipment
- Safety Equipment
- Engine Management and Control system
- Power Control and Synchronization System
- Enclosure



Coal Mine Gas - Power Plant Equipment

- Gas Source
- Dewatering
- Gas Dehydration
- Gas Compression
- Emergency Flare
- Safety Equipment
- SCADA System

- Gas Recovery System
- Gas Storage
- Gas Treatment
- Power Module
- Measurement Equipment
- Control and Monitoring System



Coal Mine Gas- Utilisation as LNG

- Applicable where:
  - Existing gas gathering and transportation infrastructure is limited
  - Best markets for gas are distant, widely distributed
  - Local electricity market (such as mine and residential use) are limited
  - Electricity sales prices are low
- Can operate on methane from mine pre-drainage and medium quality gob gas
- Mines that produce LNG on site may use it to operate mine vehicles and equipment, or may sell to a local/regional consumer
- Transportable by truck or rail

- Recent advancements in small-scale refrigeration technologies make CMM to LNG projects feasible in remote areas

Coal Mine Gas- LNG

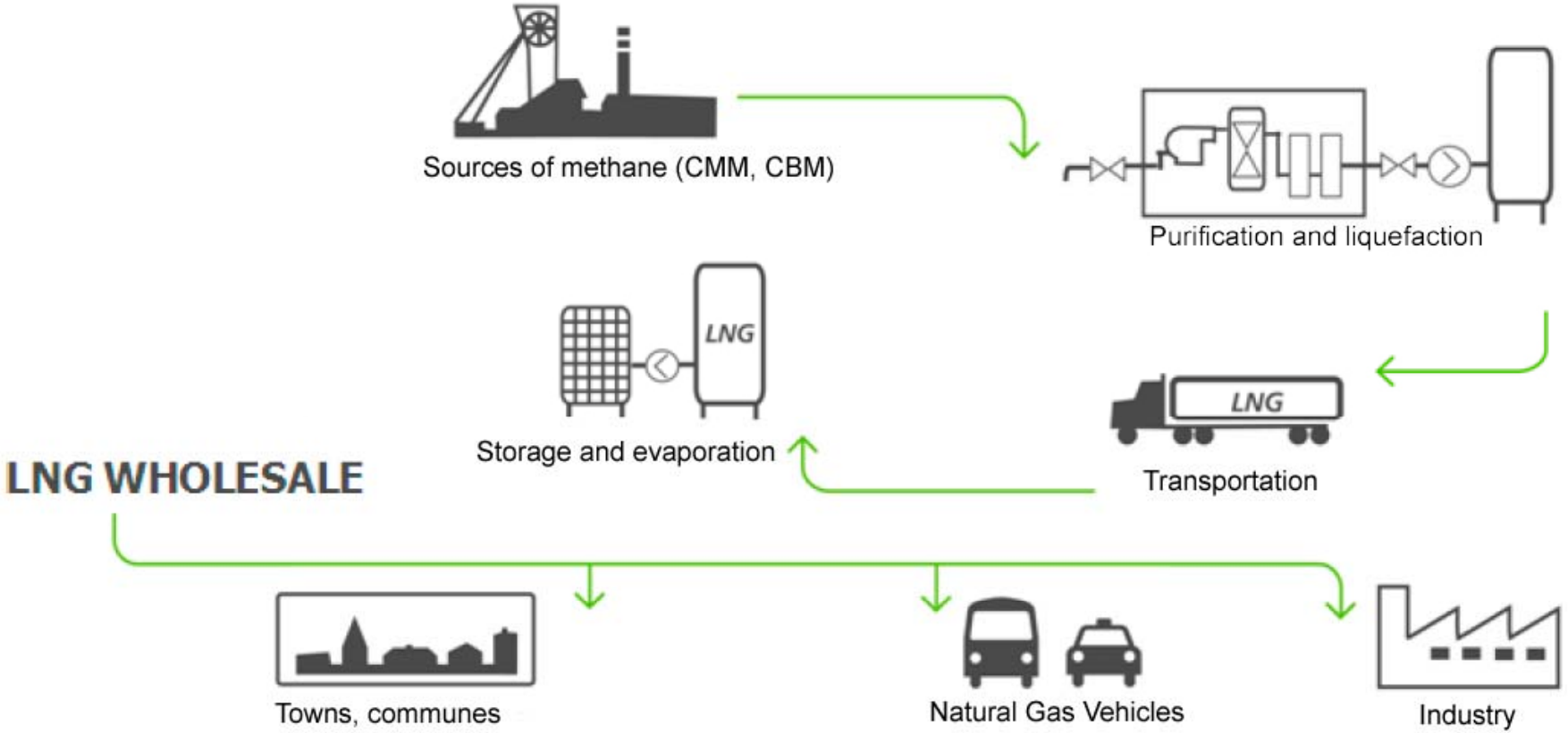
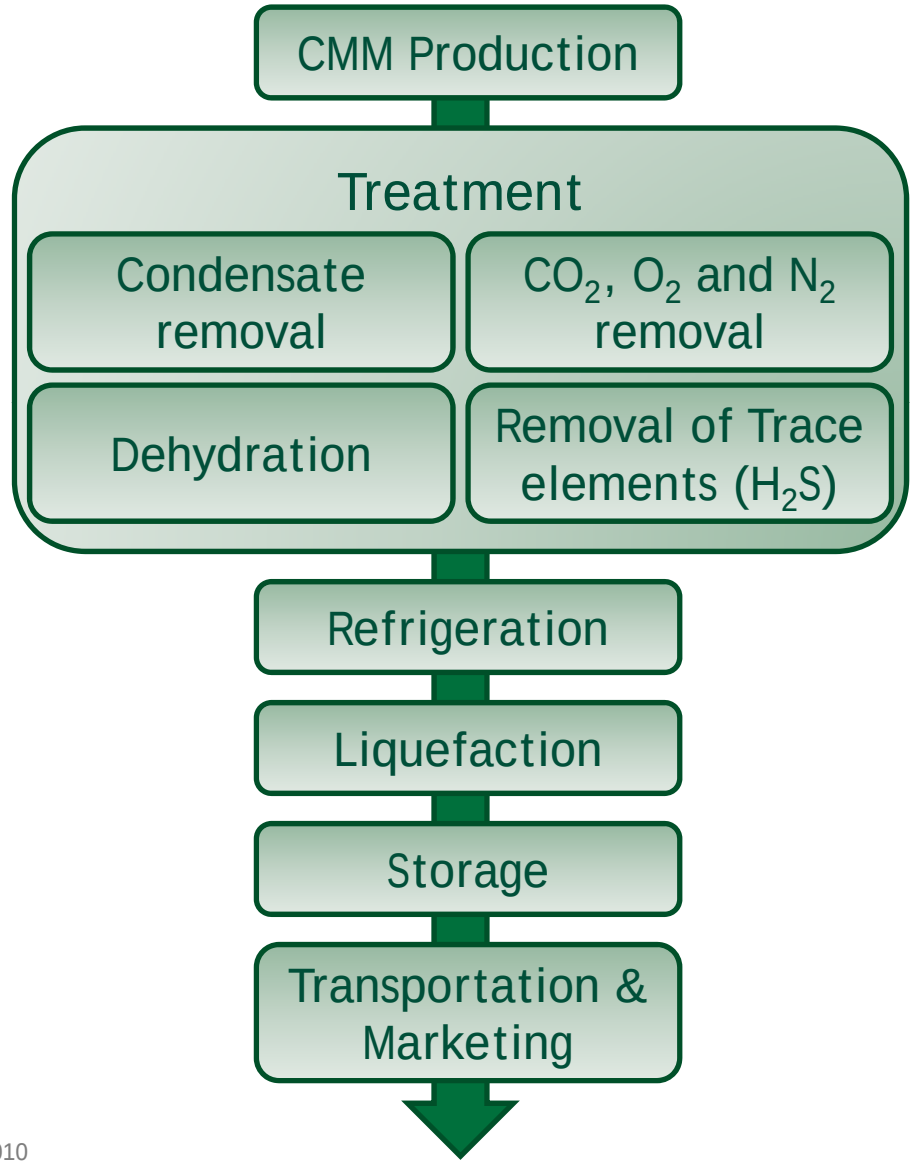


Image courtesy of LNG-Silesia

Coal Mine Gas- LNG Process



Coal Mine Gas- Utilisation as LNG

- Cryogenic N_2 removal Facility

BCCK Nitech™ Technology being used to purify CMM

Coal Mine Gas- Utilisation as LNG

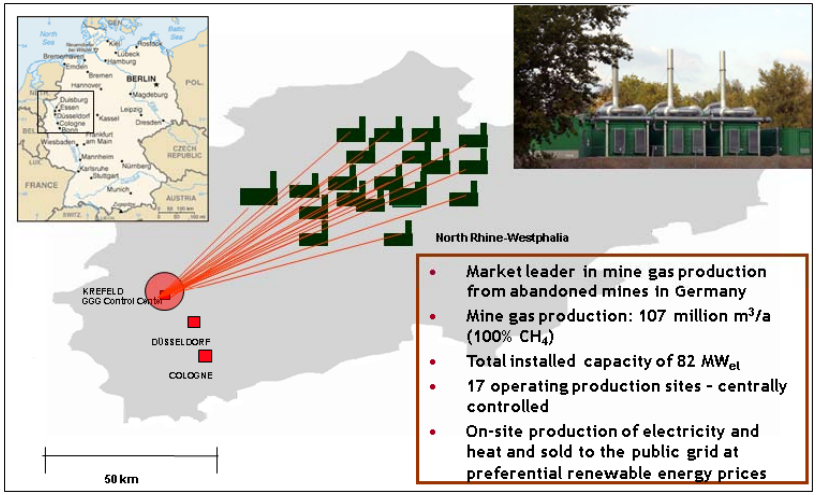
- Example of small scale LNG plant

Built by a predecessor company to Promet5heus Energy.

Coal Mine Gas - Operations & Maintenance

- Efficiency, reliability, safety and continuous improvement of operating plants
- Central Control facility in Krefeld, Germany and Ostrava, Czech Republic
  - 24/7 control and monitoring of each site using real-time data
  - Monitoring of gas quality/quantity to ensure plant optimisation
  - Collection of data for carbon credit verification
  - Provision of remote assistance & maintenance engineer, where on-site
- Operating capacity 120 Mw_{el} at 50 sites
- Annual electricity generation + 700,000 MWh_{el}

Green Gas fleet approach in the German Ruhr Area



Green Gas control centre, Krefeld

Coal Mine Gas- Use it

- CMG is a liability to the mine operator and needs to be taken care off
- CMG is a reliable clean energy source that can provide base load power
- Utilisation options in Mongolia are limited to power generation, direct use and LNG
- In order to develop, built and operate successful utilisation project we have to;
  - Analyze drainage and ventilation system
  - Optimize drainage efficiency and therefore enhance mining operation
  - Analyze utilisation options
  - Develop and design utilisation solutions to optimize production of
    - Power
    - Heat
    - Emission reductions
  - Manage gas production and plant operations to provide safe, reliable and cost competitive base load production

Coal Mine Gas – Green Gas Contacts

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