HEL East Ltd

Reserve Assessment , Pump Selection and Utilization Sizing for AMM and CMM

EPA/GMI CMM Technical Seminar
UNECE – Best Practice Workshop

Donetsk Ukraine
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Content

Introduction

- Abandoned mine methane (AMM) and coalmine methane (CMM) have many similarities. They are predominantly the same source of gas. Both are associated with coalmining. Both represent a hazard to be removed. Both offer opportunities to recover income by utilization.
- At the same time the technologies are different and offer quite different problems, requiring quite different solutions and strategies to maximize opportunity.

Introduction

- AMM has a unique advantage in that there are no men in a mine to keep safe.
- AMM can offer continuous flowrates of high quality gas.
- AMM requires no underground workers, consumables or husbandry.
- AMM is no longer linked to coal production.

Introduction

But . . .

- AMM is a finite resource.
- AMM is prone to flooding.
- AMM project pressures can range from –80 kPa to +250 kPa
- AMM can be spoiled by air leaks .
- AMM reserve evaluation is tricky.

Introduction

- CMM can be considered sustainable whilst ever coal is being mined.
- CMM drainage is often a given. Methane must be removed from many mines if production targets are to be met.
- CMM too can offer continuous flowrates of high quality gas.
- CMM gets all the resource a coalmine has to offer - regarding infrastructure, manpower and capital.
- CMM reserve is (or should be) easier to determine.

Introduction

But . . .

- CMM needs constant spend on consumables and manpower.
- CMM needs constant attention to purity (husbandry).
- CMM is linked to coal production and when it stops - even temporarily – gas flow falls – and gas quality takes a hit too.
- CMM emission rates can change when switching to different seams and also when mining is in virgin ground or not.

Introduction

Similarities between AMM and CMM projects are . . .

- Frequent over estimation of reserve potential.
- Frequent lack of design considerations of methane vacuum plants.
- A common tendency to overestimate the utilization potential in both AMM and CMM projects.

Part 1. AMM Reserve Assessment

AMM Paper Studies

AMM Drawdown Tests

Part 1. AMM Reserve Assessment

AMM Paper Studies

- Planimetery
- Coal sequence
- Mined out coal
- Theoretical voidspace
- Remaining coal
- Flooding patterns
- Gas content
- Apply Factors
- Resource
- Reserve
- Targets shafts & roadways
- Shows likely leakage paths

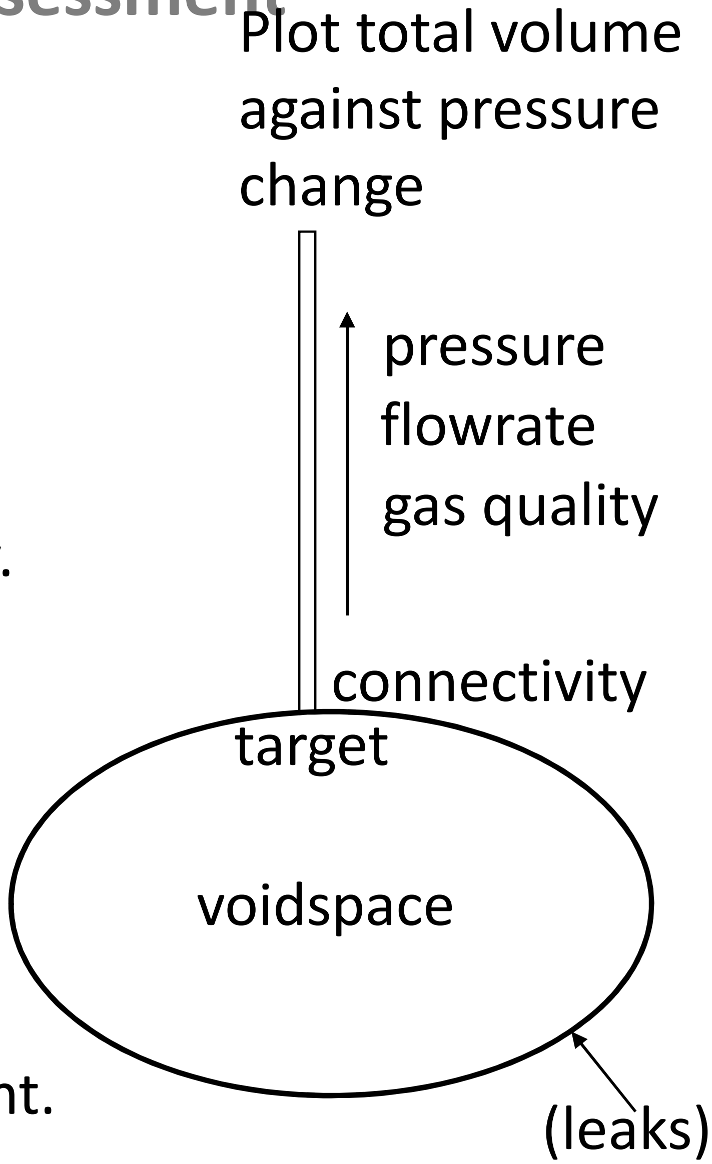
AMM Drawdown Tests

- Prove target
- Connectivity
- Flow rate
- Gas quality
- Integrity
- Voidspace
- Ante-chamber behaviour
- Confirm resource
- Apply Factors
- Confirms extraction rate
- Confirms project size

Part 1. AMM Reserve Assessment

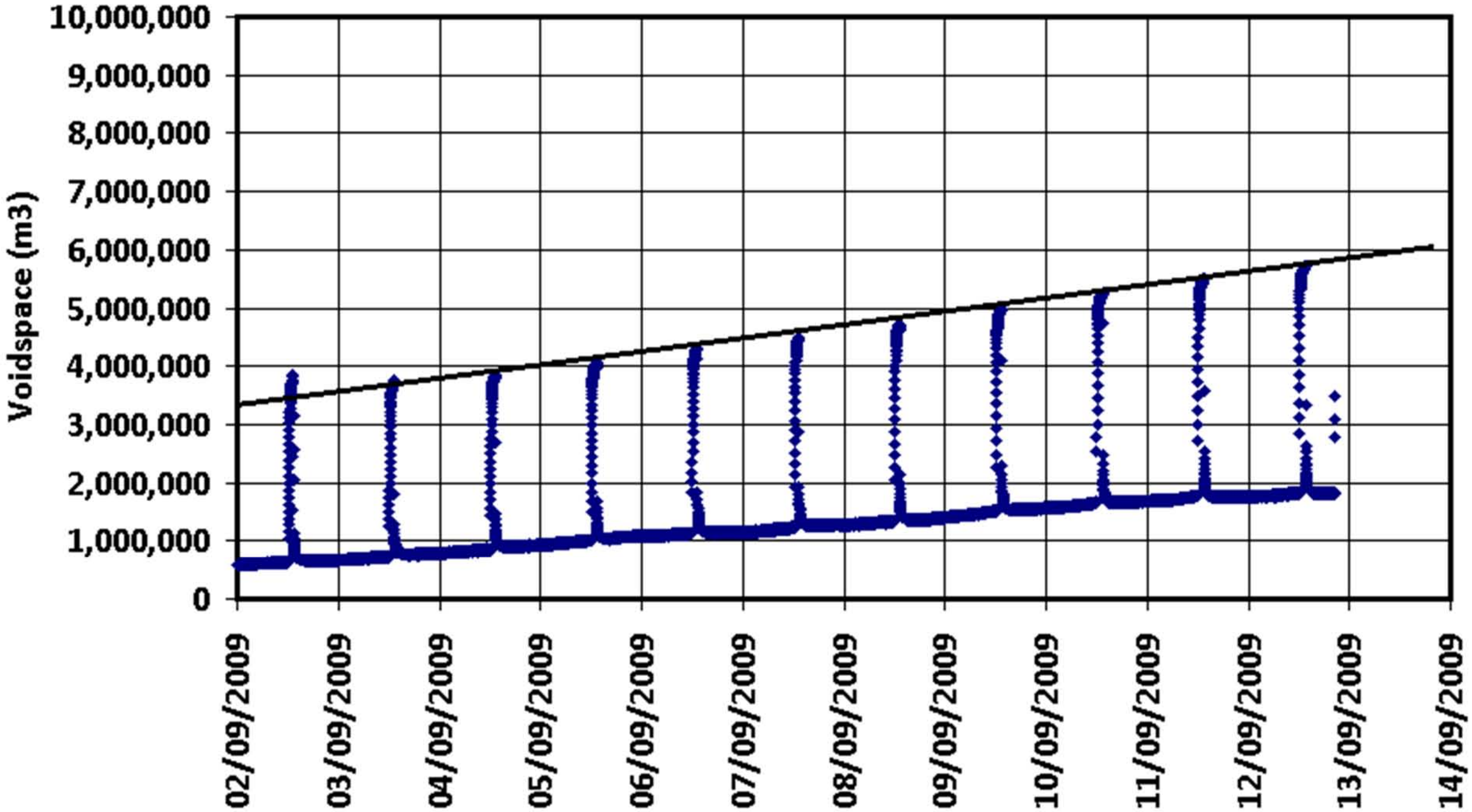
AMM Drawdown Testing

- Physical testing confirms the desktop reserve study.
- It also tests the borehole (if drilled) showing actual flow pressure losses against predicted – proving connectivity.
- Linked voids can also be detected (ante-chamber behaviour).
- Using Boyles law it is possible to make empirical judgements about the likely potential of an AMM projects success, longevity, rate and size using voidspace and gas content.



Part 1. AMM Reserve Assessment

Typical voidspace testing trace



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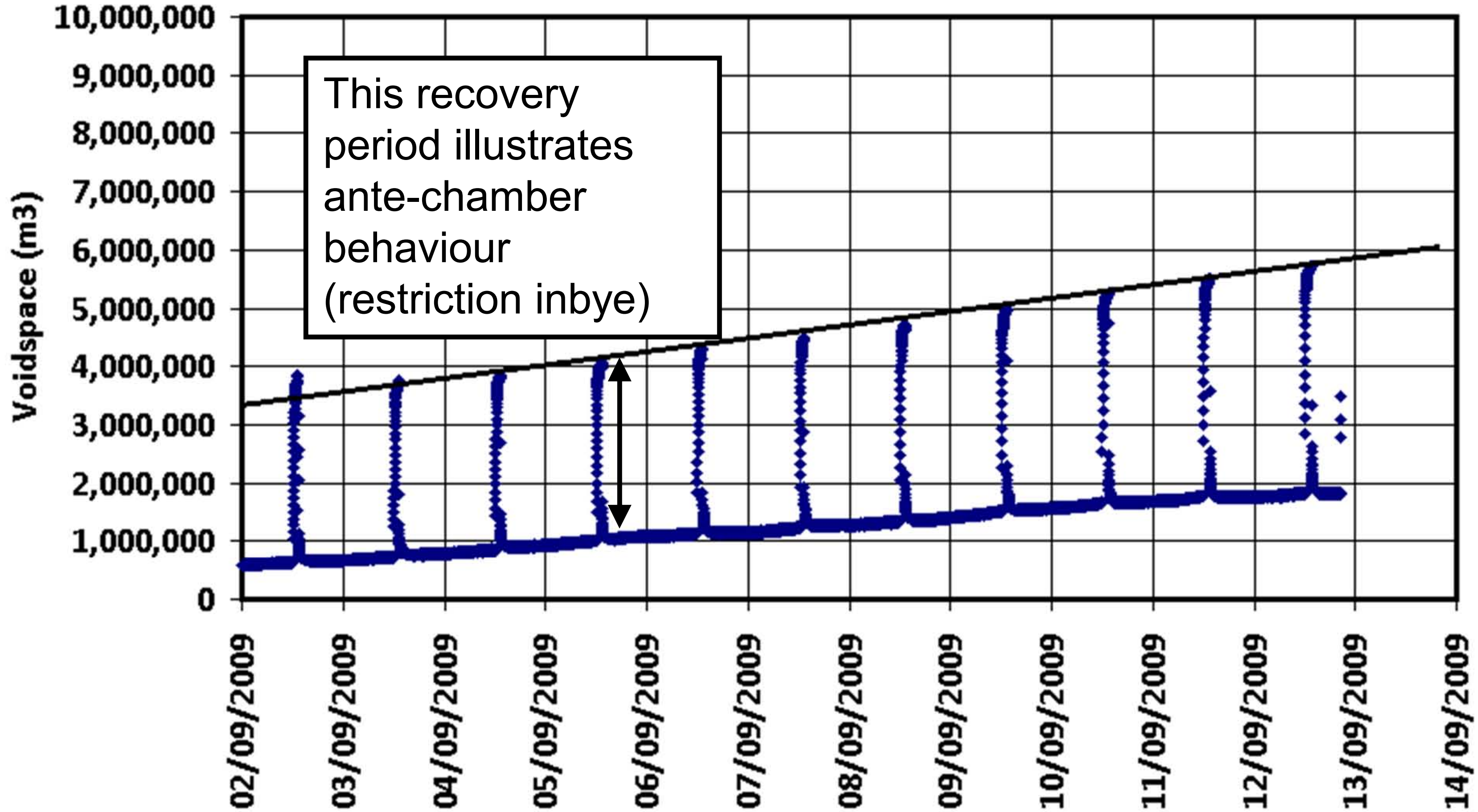
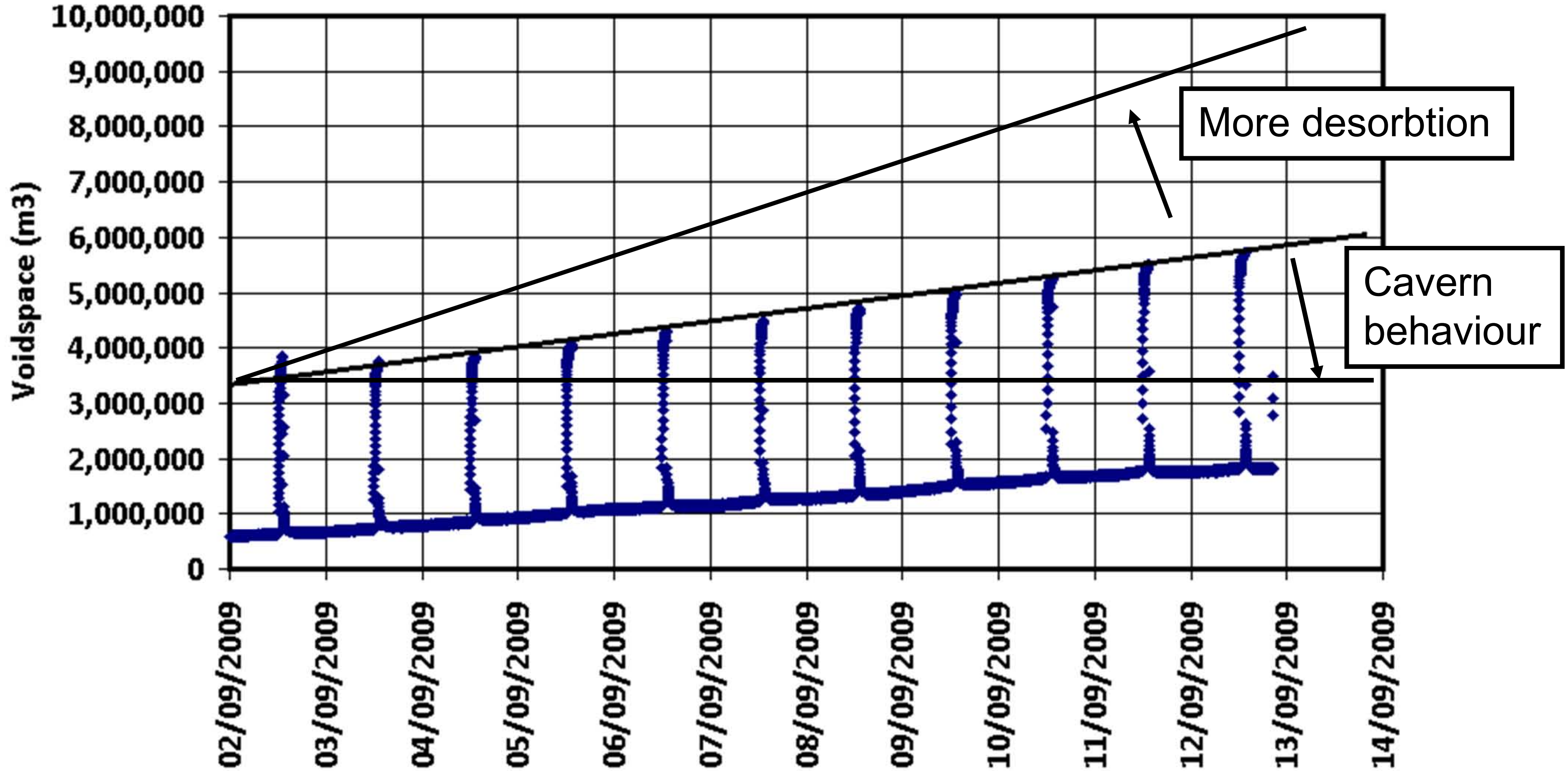


Part 1. AMM Reserve Assessment

Typical voidspace testing trace



Part 2. AMM Pump Selection

Fan Blowers

- Cheap & simple
- Safe technology
- Don't stall
- Don't overheat
- -18 kPa Vacuum
- +12 kPa Delivery
- Can be staged
- 20,000 hrs
- Low power 37kW

PD Blowers

- Mid cost
- Risk of seizure
- -55 kPa Vacuum
- +12 kPa Delivery
- Can be staged!
- 8,000 - 20,000 h
- Mid power 75kW

Liquid Ring

- Not considered

Can be staged together for dual benefits

Part 2. AMM Pump Selection

Pressure Reduction

- When abandoned mines are overpressure, all that may be required to feed gensets is a pressure reducing skid.
- The one shown in the picture is by Donkin RMG and regulated from+250 kPa down to +12 kPa.
- No pumps were needed at this site for 18 months.

Part 3. AMM Utilization Sizing

Gas Availability and Gas Quality

- Abandoned mine methane projects have no need to vent gas. They only pump what is needed for generation. No gas enters the atmosphere unburned.

- Similarly, they have little short term variation in gas quality (unless there is an air leak).

- For these reasons, genset total potential can reach >95%, only stopping for servicing.

- With this in mind, it is important to choose reliable engines with long service intervals.

Part 3. AMM Utilization Sizing

Determining Size of Genset Project

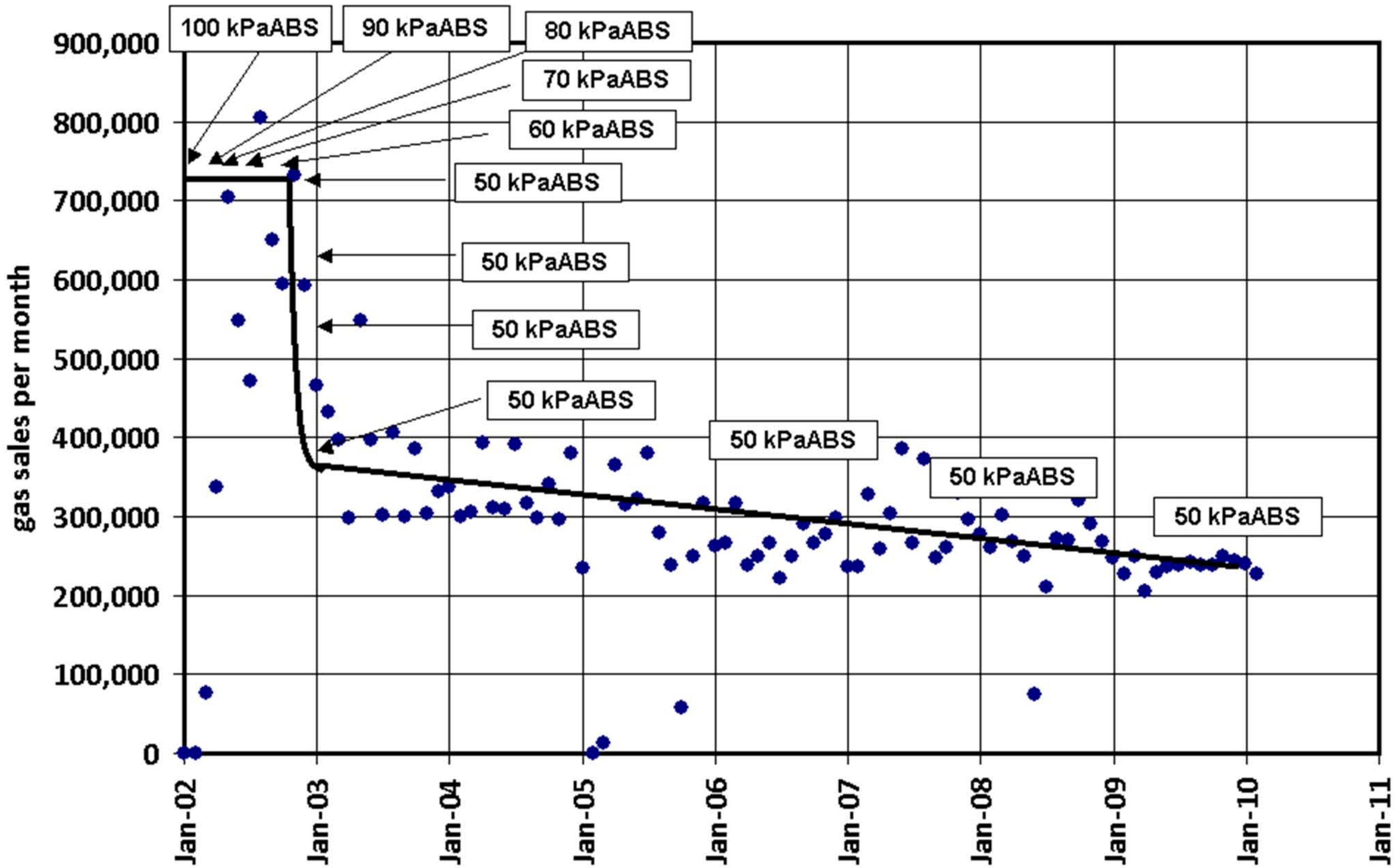
- Certainty of reserve estimate and likely equilibrium flowrate is essential. A drawdown is vital for confirmation of desktop work.

- There may be considerable "bonus gas" held in the void – before gas on coal is taken into account. This may assure initial payback.

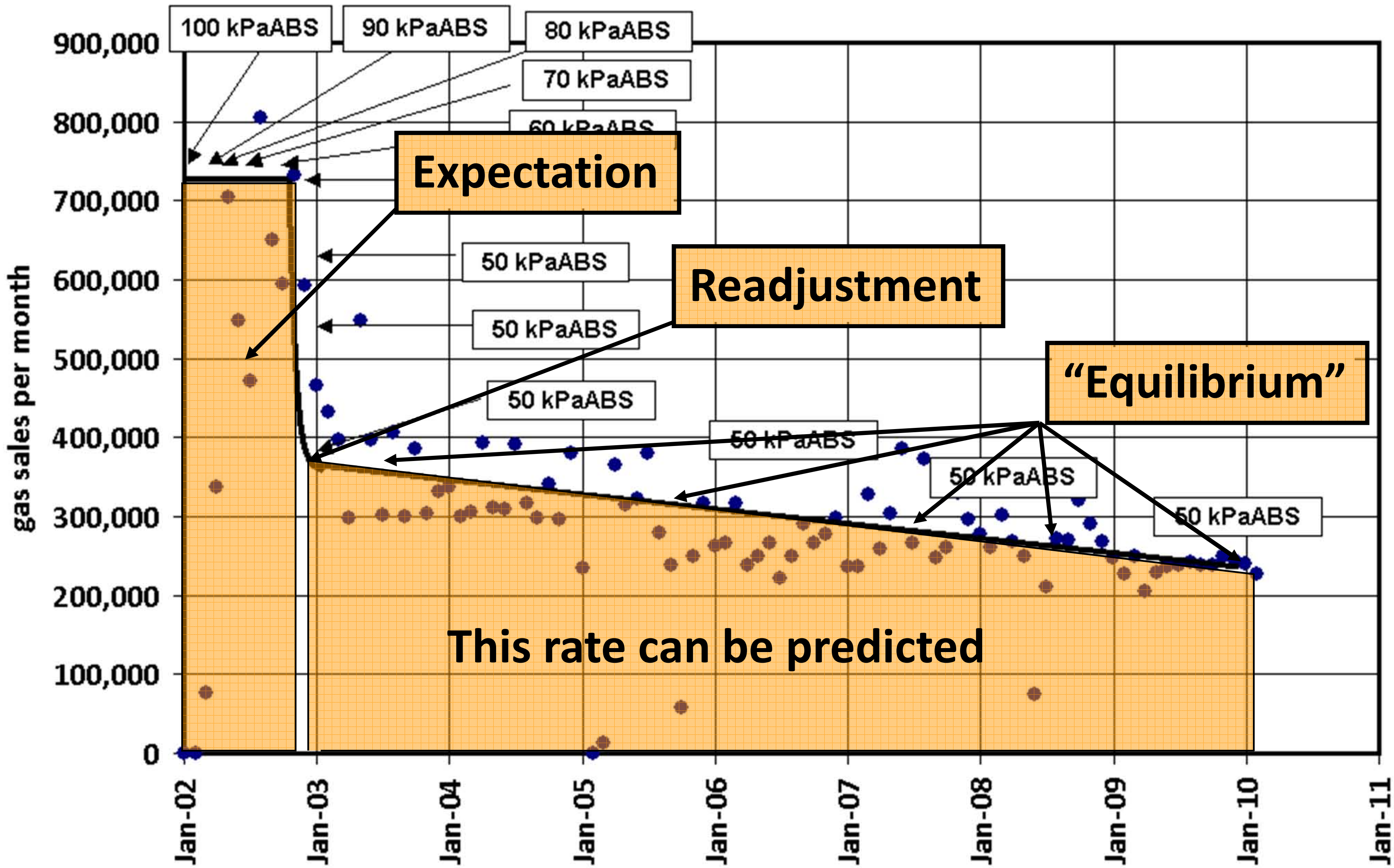
- Cost of connection to electricity grid can be high. Check with network owners before embarking on project.

- Cost of gensets – Essential IRR payback calculations required. It may be possible to lease gensets. If an organization is large – it may be able to shift gensets in and out as required.

Part 3. AMM Utilization Sizing



Part 3. AMM Utilization Sizing



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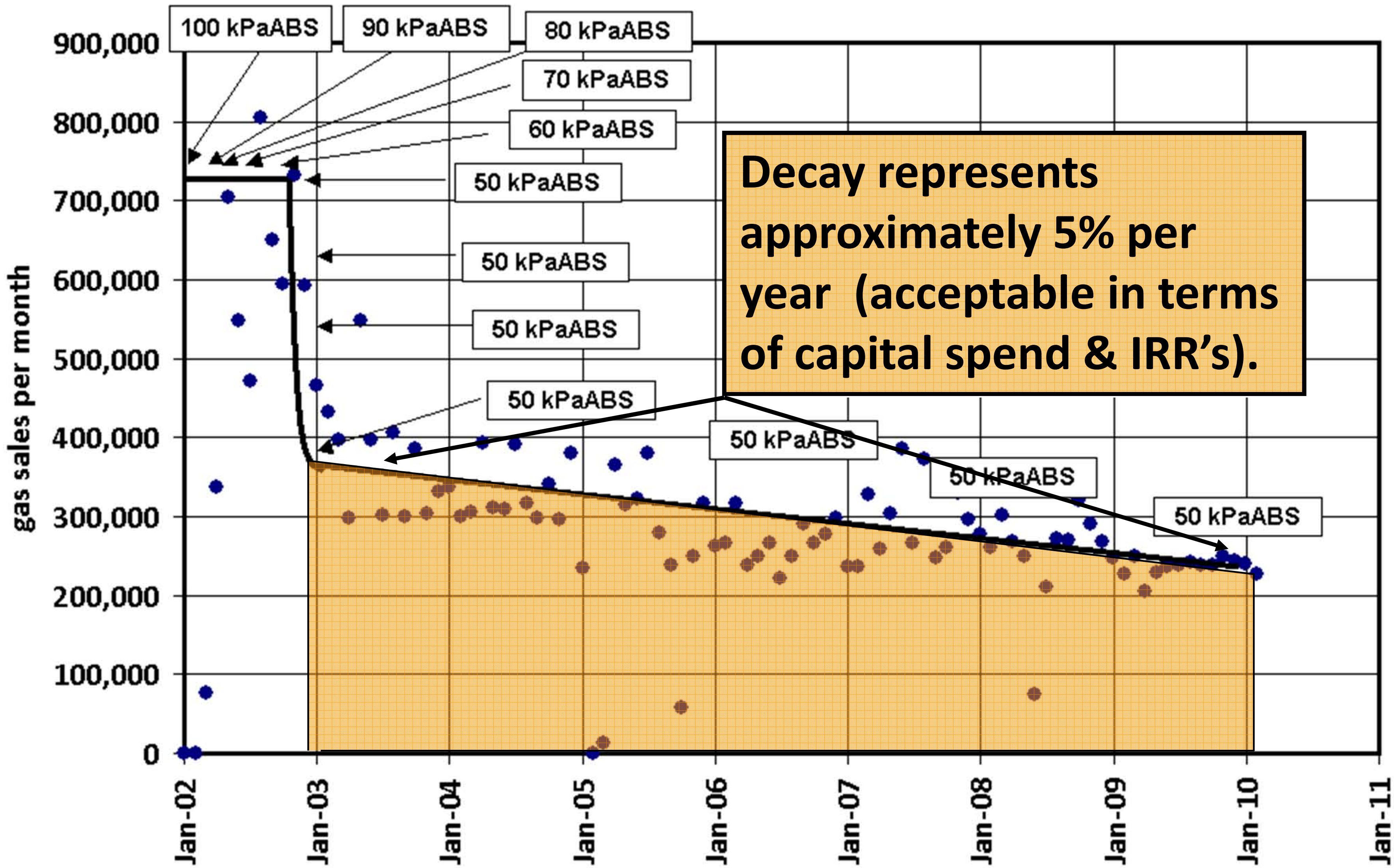


Part 4. CMM Reserve Assessment

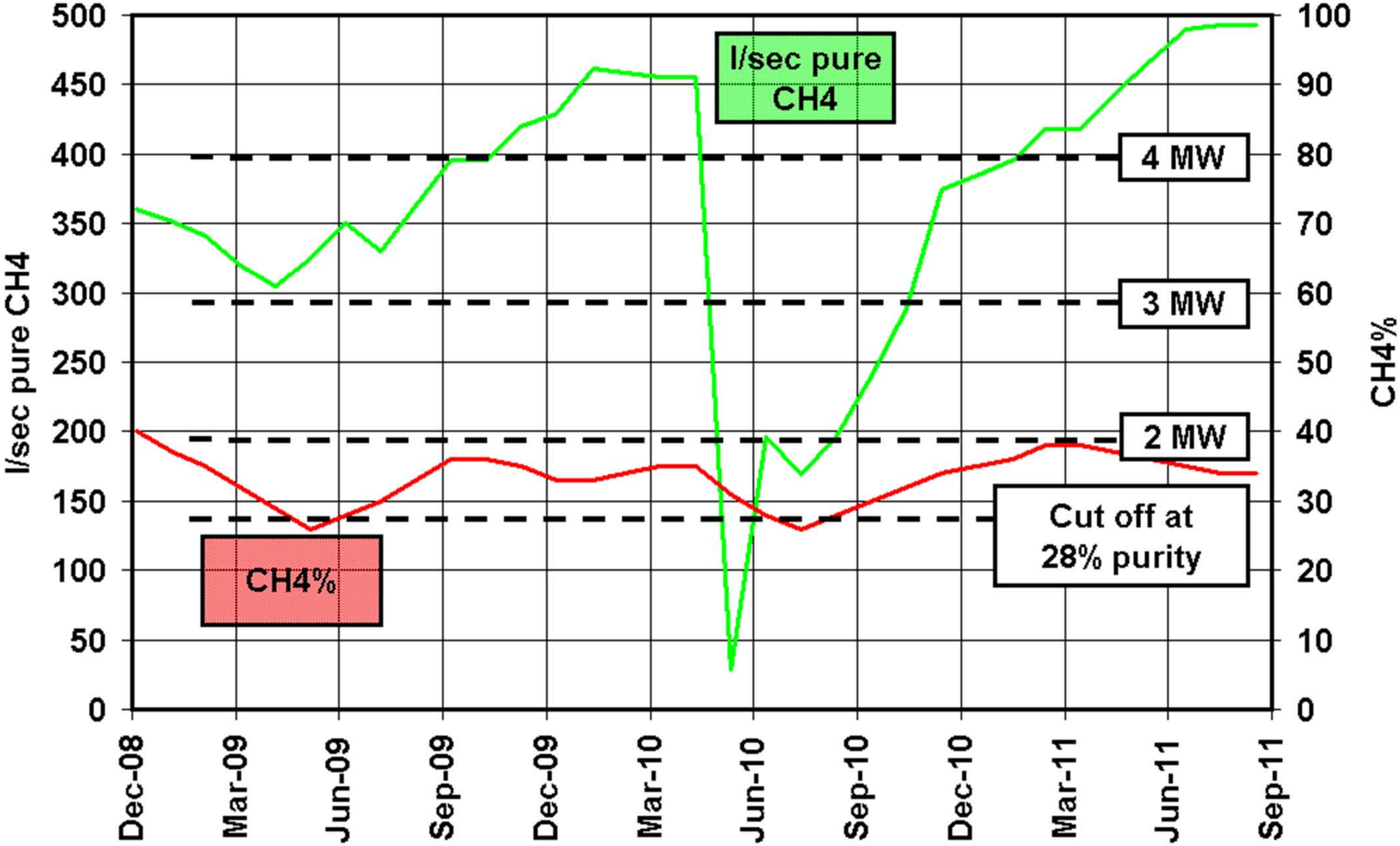
CMM Historic Performance

- Vacuum plant performance:
- Vacuum levels over time
- Gas quality over time
- Gas flow rates over time -
- correlated with coal mined
- = Total emission per tonne.
- Seam mined consistent?
- Gas content of seam?
- Method of capture consistent?
- Use all above to validate gas emission prediction package.

CMM Predicted Performance

- Vacuum plant capacity
- Vacuum capability
- Gas quality factor – use 80%
- Utilization factor – use 80%
- Check mining rate is same
- Check seam mined is same
- Check gas content is same
- Watch for over/under working
- Changes in mining method?
- Maintain capture method.
- Use validated gas emission prediction package.

Part 4. CMM Reserve Assessment



Part 5. CMM Pump Selection

Fan Blowers

- Not considered

PD Blowers

- Mid cost
- Risk of seizure
- Flametraps ATEX
- -55 kPa Vacuum
- +12 kPa Delivery
- 8,000 - 20,000 h
- Mid kW use

Liquid Ring

- High cost
- Ultra - safe tech
- -65 kPa Vacuum
- +50 kPa Delivery
- Complex – water
- +50,000 hrs
- High kW use

Part 5. CMM Pump Selection

PD Blowers

- Working mines that choose to consider PD blowers will probably be working to a cost and will appreciate the simplicity of PD blower technology.

- However, the PD blower is fundamentally a less safe design - as the pump rotor can overheat and seize in the housing. So there must be considerable safety monitoring viz. temperature and pressure and upstream and downstream ATEX flametraps must be fitted (these will have a detrimental effect on ultimate vacuum and discharge pressure performance).

- Performance is limited and gensets supply pressures should not be so high as to affect the vacuum – so affecting mine safety.

Part 5. CMM Pump Selection

Liquid Ring

- Working mines will generally have an existing methane extraction plant operating well before utilization is considered.

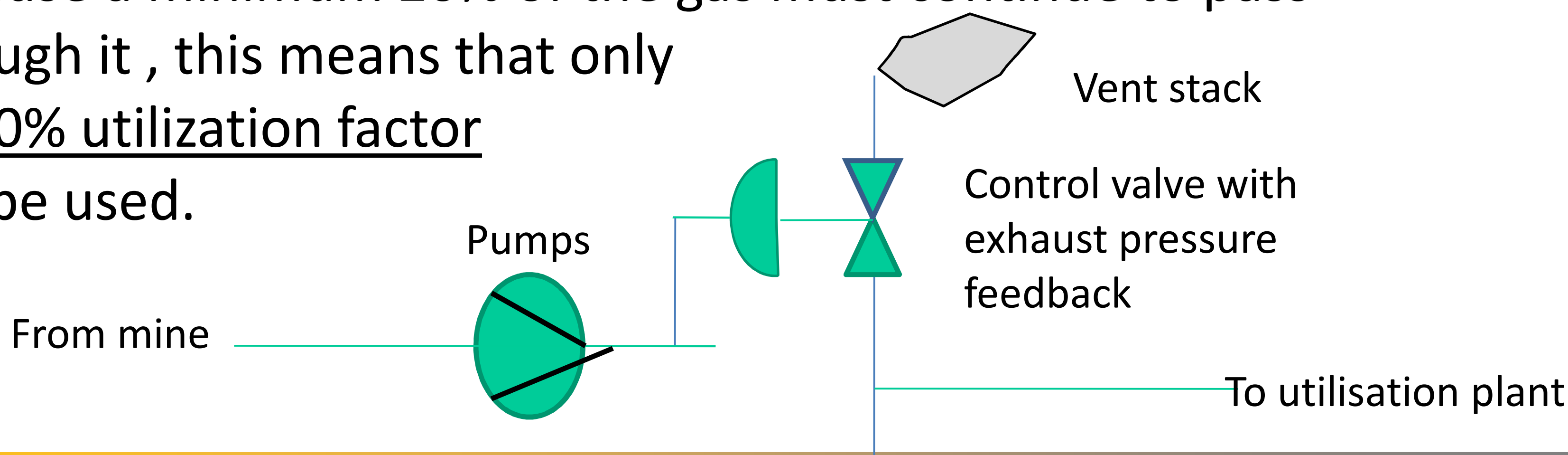
- They are most commonly liquid ring pumps, fundamentally a safe design - as the pump rotor is continually bathed in water. There must be sufficient volume capacity to feed gensets and "live" spare capacity as swap-outs can be a lengthy procedure.

- Purity can be controlled to a degree - by increasing or decreasing suction pressure – providing it does not compromise underground operations. This can be done by altering numbers of pumps or by modulating a recirculation valve.

Part 6. CMM Utilization Sizing

<u>Back Pressure Relief Valve</u>

- In CMM utilization systems, back pressure on the exhaust of the pumps is controlled by a variable by-pass valve en-route to the stack, which allows the venting of excess gas.The outlet pipe is essentially a fuel supply manifold at +15 kPa pressure.
- The pressure relief is constantly and immediately available - as all gas must always continue to be drained from the mine.
- Because a minimum 20% of the gas must continue to pass through it , this means that only an <u>80% utilization factor</u> can be used.



Part 6. CMM Utilization Sizing

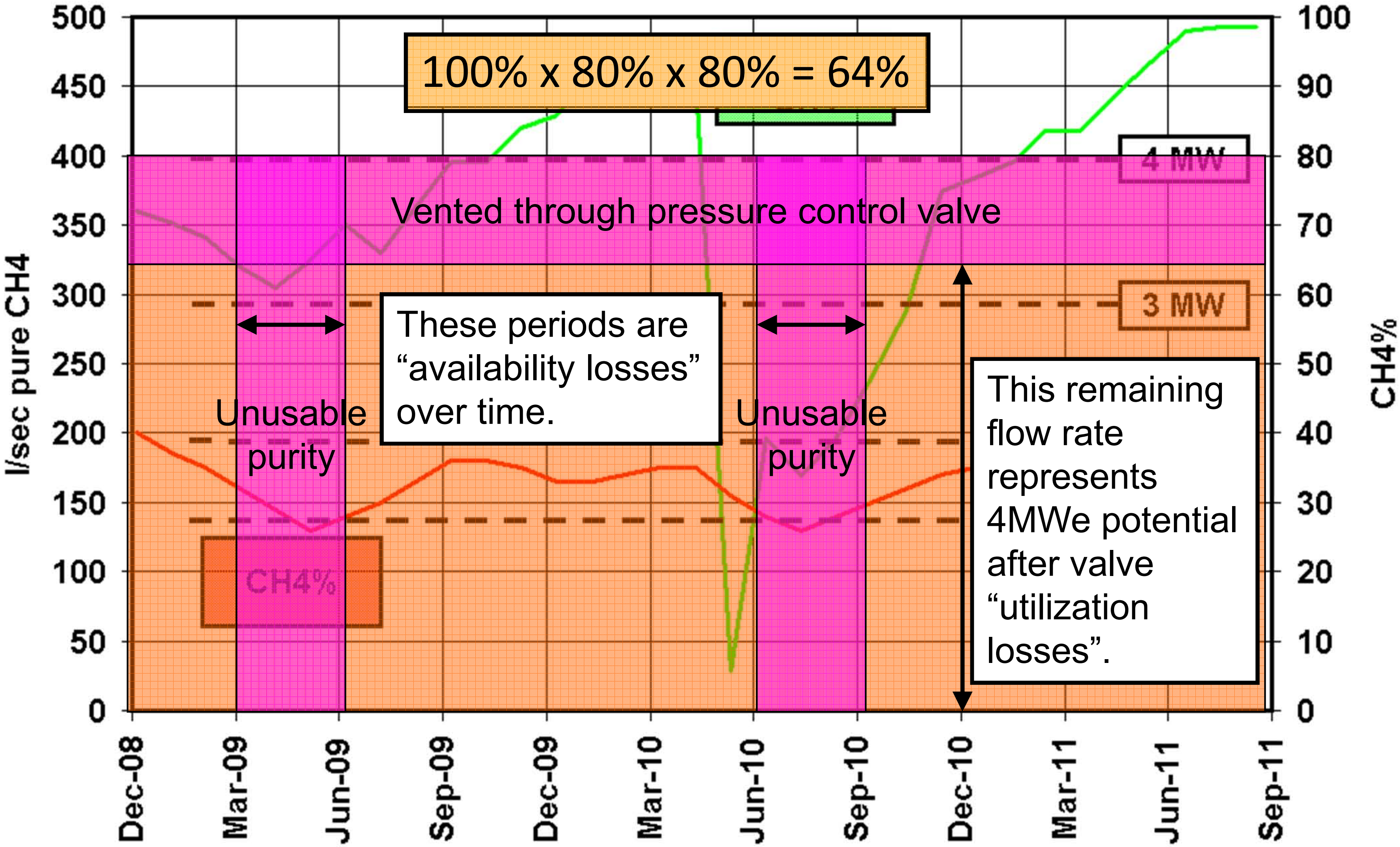
Gas Availability

- In addition, gas quality can be unusable at times , meaning it is best to apply an 80% availability factor.

- The utilization 80% factor multiplied by the availability 80% factor means a combined factor of 64% should be applied to the likely gas reserve flow generation rate potential.

(In practice, this has been borne out in the UK at working mines where machine generation MWh rates are operating at between 60% to 65% of the maximum theoretical potential from of drained gas).

Part 6. CMM Utilization Sizing



Part 6. CMM Utilization Sizing

- In the example shown, the 400 l/sec pure CH4 multiplied by the <u>80% utilization factor</u> means a useful 320 l/sec pure CH4 is available for power generation.

- At a higher heating value of 37.71 MJ/m3, this rate of CH4 flow equates to an energy flow of 12 MJ/sec or 12MWch.

- A typical efficiency for reciprocating engine gensets is 33%.

- This means that the flow could fuel 4MWe of genset.

- The <u>availability factor of 80%</u> means that it can do this for 80% of the time. Expectation of 35,040 MW hours is reduced to 28,032 MW hours. Servicing can be fitted into the stop times.

Part 6. CMM Utilization Sizing

Size of Utilization Plant

- The quantity of gas being drained from the mine will determine the size of plant.
- A cut-off point will be decided where the energy flow within the gas is insufficient to deliver payback on the cost of the smallest divisor of genset modules. IRR modelling can demonstrate this well.
- Future production schedules may change and providing the same seam in the same geology is being worked and providing there is spare capacity in the methane extraction plant's volume capacity (and drilling teams can keep pace), then gas emissions and capture levels should be pro-rata – leading to a pro rata increase in energy flow. This may be taken into account when sizing plant for the future.

Part 7. Genset Discussion

Reciprocating Engine Genset Packages versus Turbines

Reciprocating Engines

- 0.5MW to 3MW size range
- Very efficient (33% on HHV)
- Low parasitics
- Low CH4 concentration (28%)
- Manageable technology
- Easy to containerize
- Many suppliers = competition.
- +50,000 hrs before major work
- $1.6M per 1MW (for 5 x 1MW)
- Split duty = high efficiency.
- Can tolerate variable supply

Turbines

- Long service intervals
- Very reliable (1 rotating shaft)
- Becoming more efficient 22-40%
- Can be combined cycle (60% eff)
- Sizes 0.5MW to 250MW
- High parasitics
- CH4 concentration >40%
- 25,000hrs to 50,000 hrs interval
- $1.3M per 1MW (for 1 x 5MW)
- Need reserve and yield certainty

(EPA Dec 2008 "Technology characterization" of recip & turbine gensets)

Part 7. Genset Discussion

Reciprocating Engine Genset Packages versus Turbines

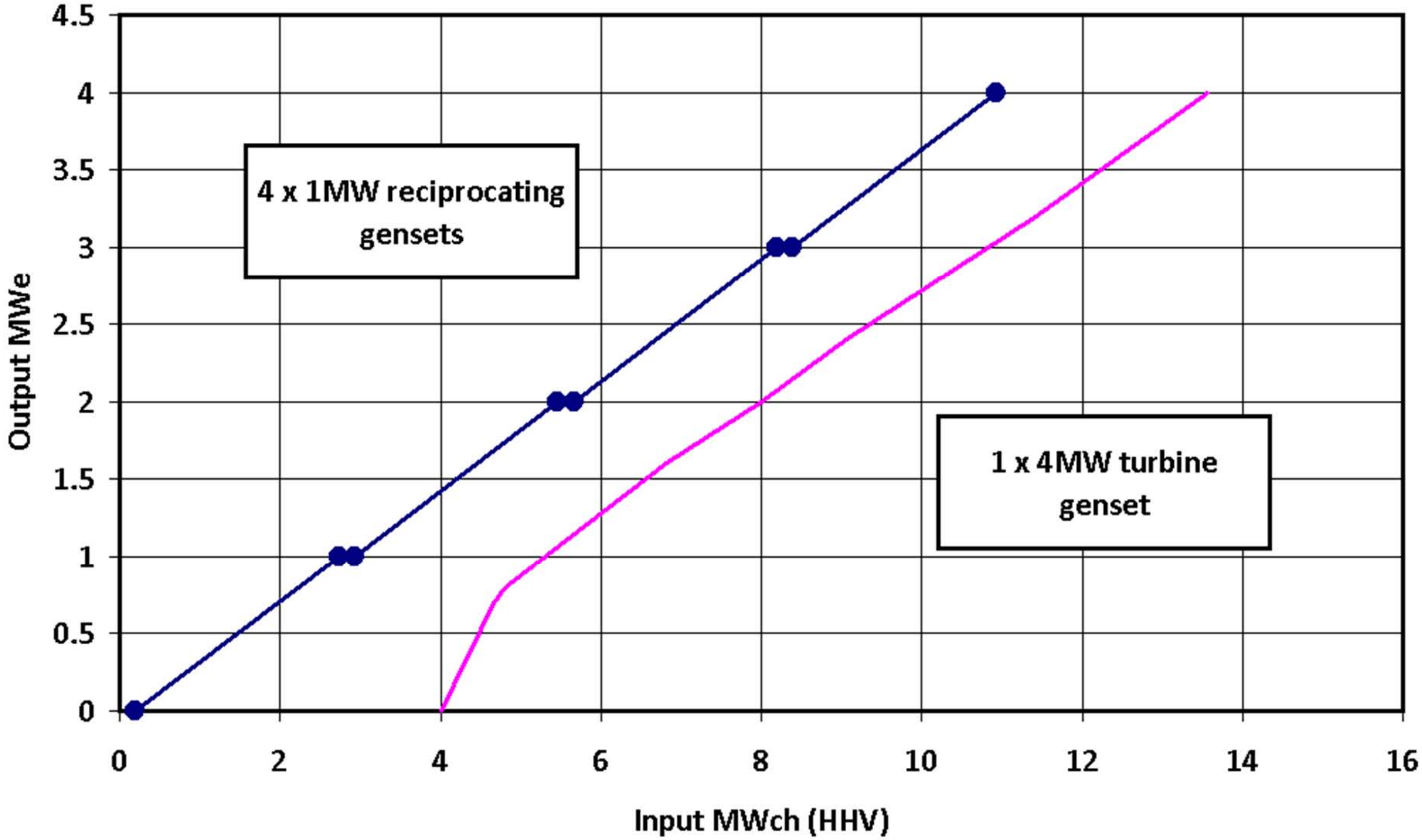
12 MWe reciprocating genset package 4 x 3MW containers (33%eff)

14 MWe after parasitics (28%eff)
2 x 4MW turbines (alone = 22%eff)
1 x 10MW Steam set (assists effy)

(typical efficiencies calculated on an HHV energy input basis)

Part 7. Genset Discussion

Reciprocating Engine Genset Packages versus Turbines



(Efficiencies derived from EPA Dec 2008 "Technology characterization" of recip & turbine gensets)

Part 7. Genset Discussion

Containerized Plant versus Fixed Buildings

Containerized Plant

- Allows for flexibility
- Creates transferrable asset
- Factory made–quality assured
- Possible rental
- Bankable asset to borrow off

Fixed Building

- More costly
- Appears more prestigious
- Can be used as base & for stores
- Better in severe climates
- Can house large projects easily

Hybrid of Containers in a Building

- Most costly – but building can be cheaper – a “cowbarn” shell.
- Double protection from severe climates.
- Has all advantages of both.
- Building can still have use if project stops but mine continues.

Part 8. Conclusions

- Choose fan blowers or roots blowers for AMM
- Choose roots blowers or liquid ring pumps for CMM
- AMM utilization projects are frequently oversized so desktop and drawdown reserve evaluation is essential.
- CMM utilization projects are frequently oversized so historic trending and future emission prediction is essential.
- CMM utilization projects need 80% availability and 80% utilization factors applying to give 64% combined.
- Containerize and choose multi–recip over single large turbine