Developing a Diverse CMM Industry including VAM Utilisation

Dr Cliff Mallett
Acting Chief, CSIRO Exploration and Mining
Technology Court, Pullenvale, Qld 4069, Australia
cliff.mallett@csiro.au

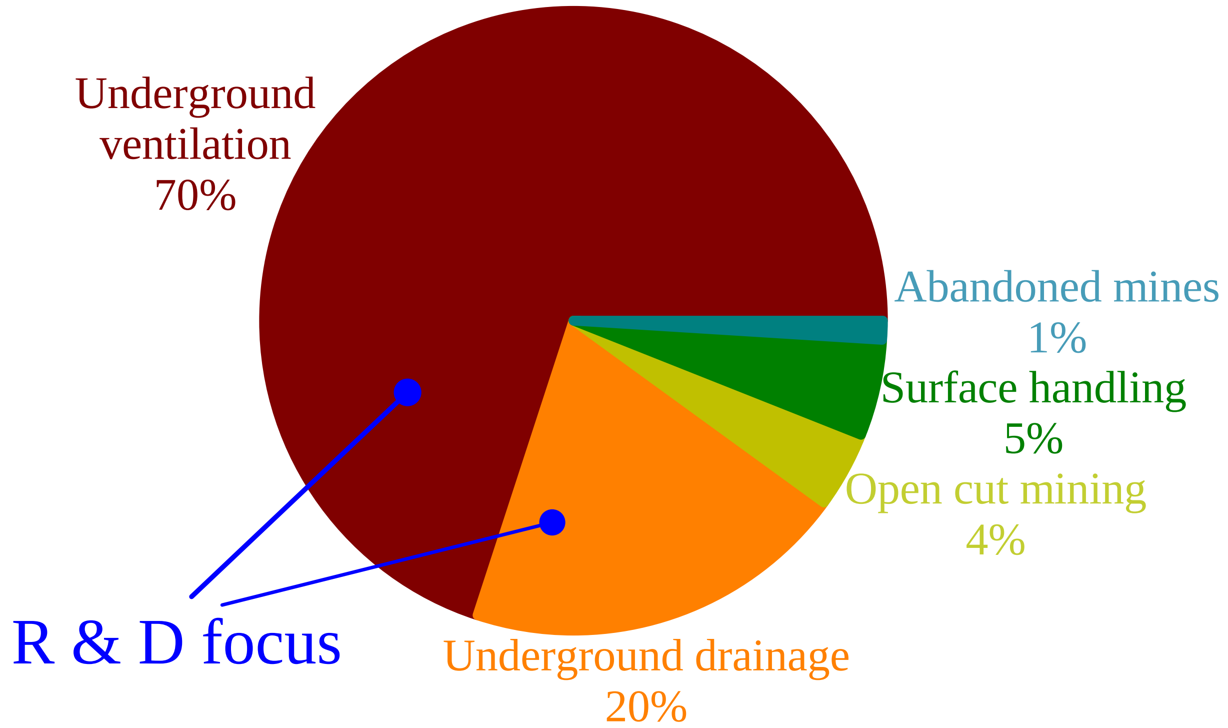
❑Coal mine methane emissions-1

❖ *Mine CH_4:*

In Australia: ~6% of GHG production

World total: VAM - over 200 MMT CO_{2e} in 2000 (from US EPA report).

❖ *Coal-related methane emission sources:*



from IEA report

CSIRO

❑Mine methane emissions-2

❖*Underground*

✓PRE-DRAINAGE

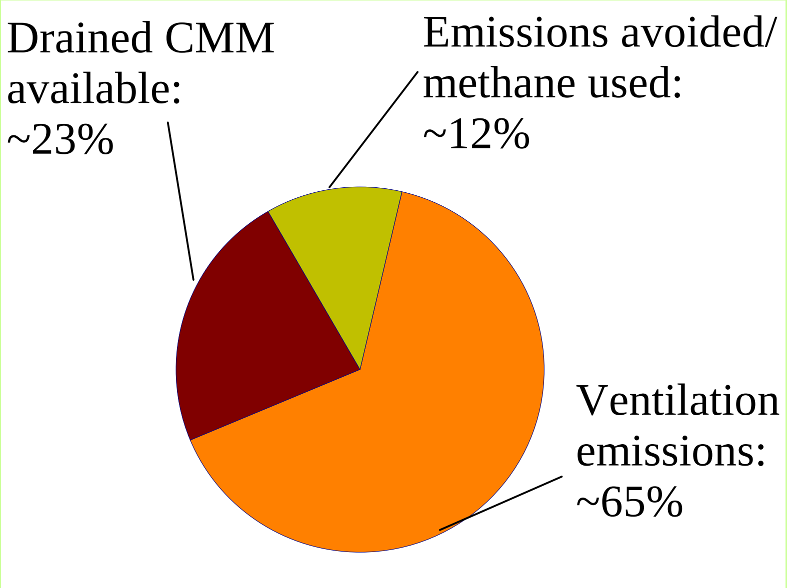
- High CH_4 conc ~ 95%,
- Relatively consistent flow.

✓POST-DRAINAGE

- Medium CH_4 conc ~(>30%),
- Rapid change in flow rate.

✓VENTILATION AIR

- <u>Huge amount, 150~300m^3/s</u>
- <u>Variable CH_4 conc <1%.</u>
- <u>Most difficult to use</u>



Underground CMM liberation

(estimated based on mine-site data)

❑What can we do with the mine methane?

Combustion

thermal oxidation

catalytic oxidation

Purification to make pipeline gas

Feedstock for chemicals

methanol

carbon black

❑Map of potential technologies

Mine Methane				
Low Concentration		Medium-High Concentration		Hybrid
Mitigation	Use	Mitigation	Use	Use
Thermal TFRR, Catalytic CFRR, Catalytic CMR.	Catalytic turbine, Recuperative turbine, Catalytic + 2nd heat, Power station air, Air for engines, Air for turbines, Concentrator (?)	Flare.	Purify, Gas engines, Gas turbines, Fuel cells, Co-firing, Feedstock.	Fluidised bed, Rotating kiln.

CSIRO

❑Technologies for drainage gas

- ❖*Purification: pipeline gas*
- ❖*Power generation/cogeneration*
  - Reciprocating gas engine
  - Conventional gas turbine
  - Co-firing in power stations
  - Fuel cell power generation
    (electrochemical reaction)
- ❖*Chemical feedstocks*
  - Methanol production
  - Carbon black production

❑ Technologies for ventilation air methane -1

❖ *Ancillary uses*

substituting the ventilation air for ambient air in combustion processes

Limited sites or small volumes used not in case studies

❖ *Principal uses*

combustion of the methane in ventilation air as a primary fuel

- *Thermal flow-reversal reactor (TFRR),*
- *Catalytic flow-reversal reactor (CFRR),*
- *Catalytic monolith reactor (CMR),*
- *Catalytic lean-burn gas turbine,*
- *Recuperative lean-burn gas turbine,*
- *Enriching process (?, not in case studies)*

CSIRO

Technologies for ventilation air methane - 2

Principal use technologies

CH_4 mitigation

Feature	MEGTEC TFRR	CANMET CFRR	CSIRO CMR
Principles of operation	Flow reversal	Same as TFRR	Monolith reactor
Catalyst	No	Yes	Yes
Auto-ignition temperature	1000^{o}C	350~800^{o}C	500^{o}C
Experience	Some field units operating on methane	Bench-scale trials with simulated mine exhaust	Bench-scale study on combustion
Cycle period length	Shorter	Longer	Continuously
Minimum CH_4 concentration	0.2%	0.1%	0.4%
Applicability	CH_4 mitigation	CH_4 mitigation	CH_4 mitigation
Possibility of recovering heat to generate power	Need additional fuel to increase CH_4 concentration and maintain it constant	Need additional fuel to increase CH_4 concentration and maintain it constant	Need additional fuel to increase CH_4 concentration and maintain it constant
Variability of CH_4 concentration	Variable	Variable	Variable
Plant size	Huge	Larger	Compact
Operation	More complicated	More complicated	Simple
Lifetime	N/A	N/A	>8,000 hours for catalysts,
NO_x emission	N/A	Low	Low (<1ppm)
CO emission	Low	Low	Low (~0ppm)

All need extra fuel added to VAM to generate power

CSIRO

Technologies for ventilation air methane - 3

CH_4 mitigation & utilisation

Feature	EDL Recuperative Turbine	CSIRO Catalytic Turbine	Ingersol-Rand Catalytic Microturbine
Principles of operation	Air heater inside combustion chamber	Monolith reactor	Monolith reactor
Catalyst	No	Yes	Yes
Auto-ignition temperature	700~1000°C	500°C	N/A
Experience	Pilot-scale trial	Bench-scale study on combustion	Conventional microturbine development
Cycle period length	Continuously	Continuously	Continuously
Minimum CH_4 concentration for operation	1.6%	1%	1%
Applicability	CH_4 mitigation and power generation and need additional fuel to increase CH_4 concentration	CH_4 mitigation and power generation and need additional fuel to increase CH_4 concentration	CH_4 mitigation and power generation and need additional fuel to increase CH_4 concentration
Possibility of recovering heat	Feasible (power generation)	Feasible (power generation)	Feasible (power generation)
Variability of CH_4 concentration	Constant	Constant	Constant
Operation	Simple and stable	Simple and stable	Simple and stable
Lifetime	May be shorter due to the high temperature combustion heat exchanger	>8,000 hours for catalysts, and 20years for a turbine.	N/A
NO_x emission	N/A	Low (<3ppm)	Low
CO emission	Low	Low (~0ppm)	Low

❑Technologies for ventilation air methane & drainage gas

- *No single technology provides an easy solution*

- *Combined units can give benefits*

  Example: 1% methane turbine and conventional gas engine power plant system can maximise the mitigation and utilisation of all of mine methane.

❑Case studies of two mines

Technical & economic assessment of the implementation of most of the above technologies into an Australian mine

Technical feasibility

- Range of technologies, 95% availability, maximum capacity

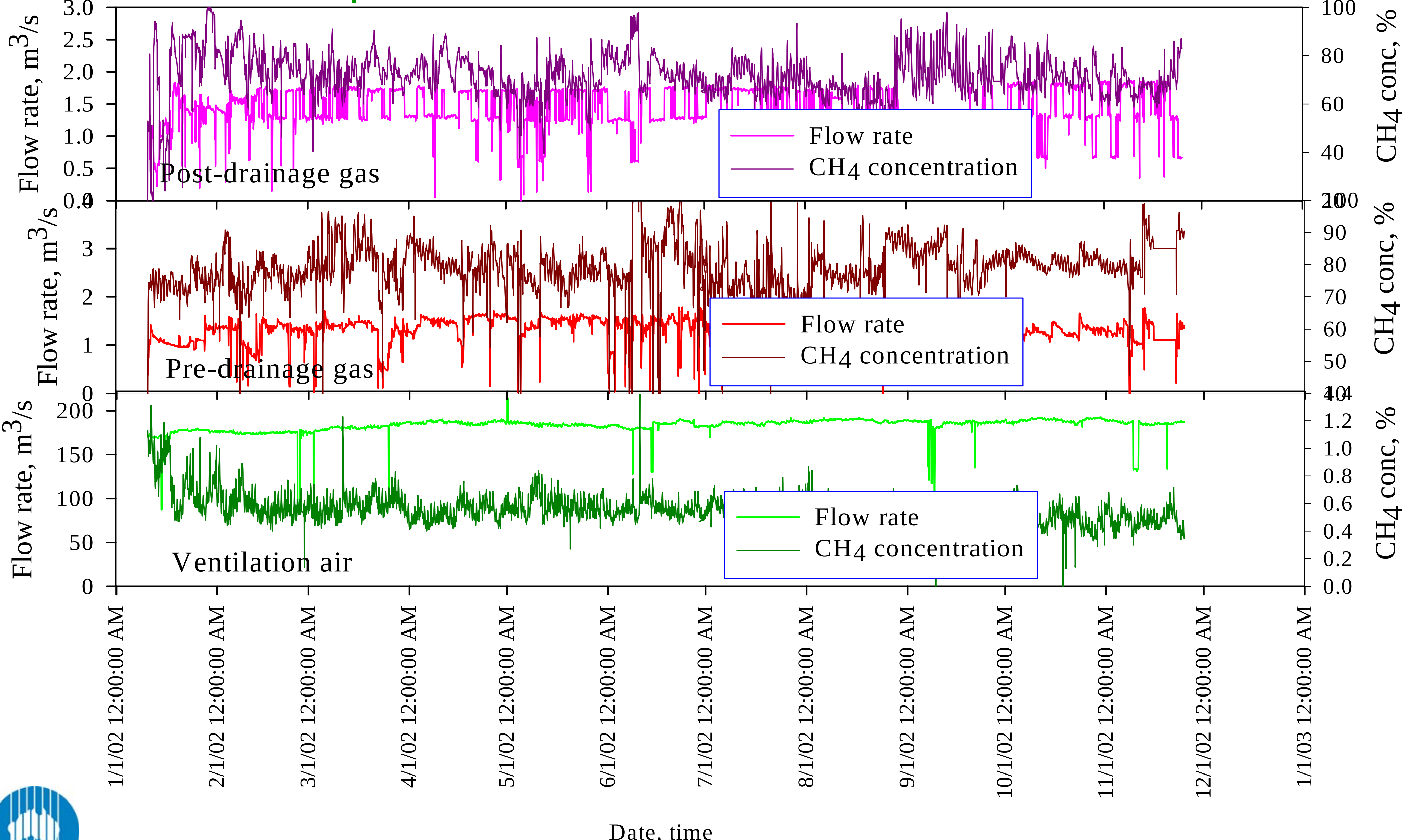
Economics

- determine major economic parameters: capital cost, operational cost, IRR, net present value, break-even cost
- basic case
  - plant lifetime: 25 years,
  - installation cost: 10% of equipment capital cost,
  - discount rate: 7.5%,
  - electricity price: AU$37/MW•hr,
  - natural gas price: $5.05/GJ,
  - no carbon credit.

CSIRO

❑ Case study-Mine 1

❖CH_4 emissions at mine



CSIRO

❑ Case study-Mine 1

CH_4 emissions at mine

(Based on average values)

Vent air: 32,433,515 m^3/year, 32.8%

Drainage: 66,475,933 m^3/year, 67.2%

Mine ventilation methane is contained in 5.4 billion m^3 of air

CSIRO

❑ Case study-Mine 1

CH_4 at mine site

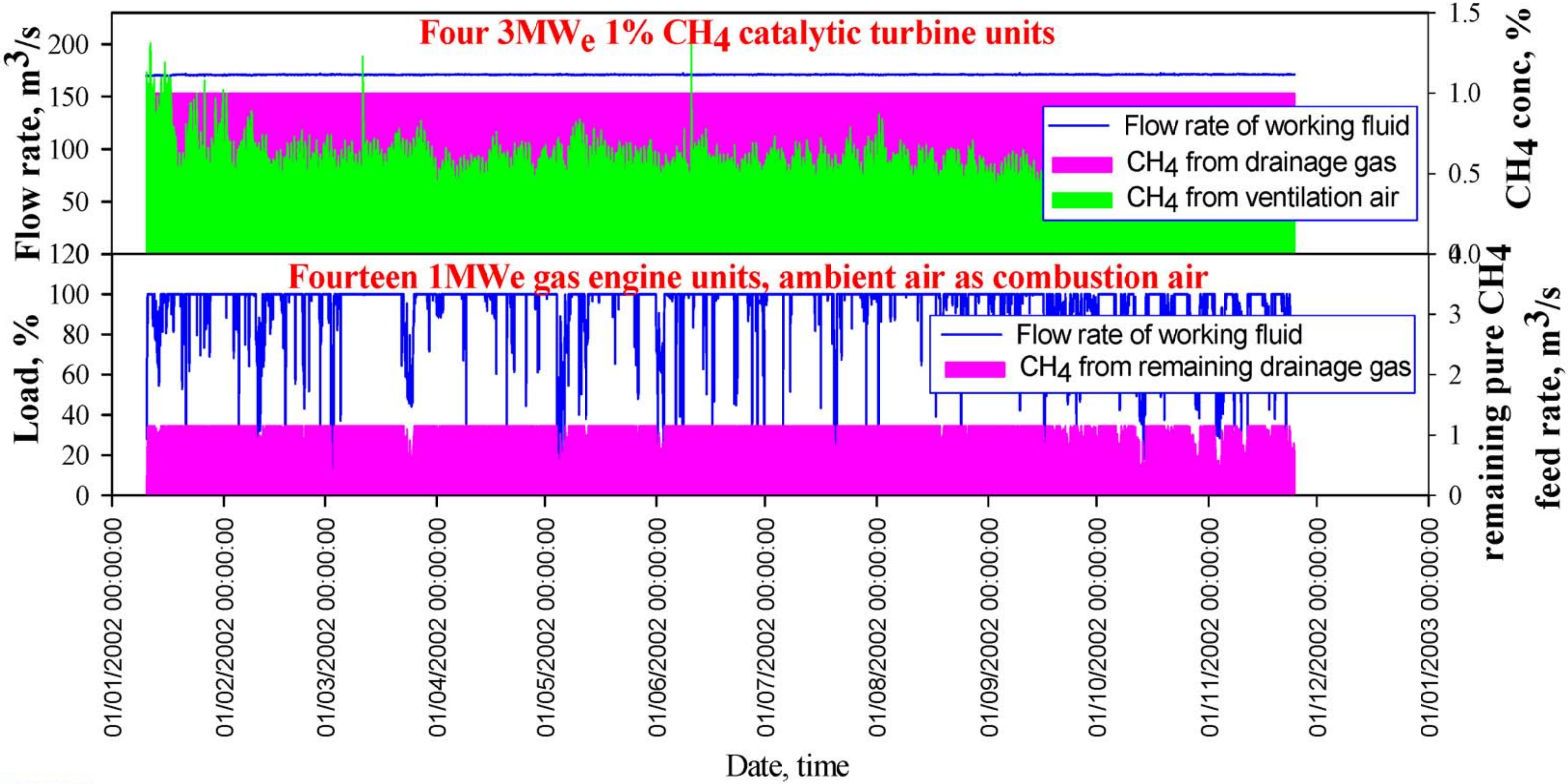
- ✓ Biggest CH_4 concentration variation rate: 0.01%/hour in vent air
- ✓ CH_4 in Ventilation air: min 0.2%, max1.44%, average 0.56%
- ✓ CH_4 in drainage gas: average 79.2% for Pre, 71.8% for Post
- ✓ Pure CH_4 flow in drain gas: 2.11m^3/s

CSIRO

❑ Case study-Mine 1

Operating status

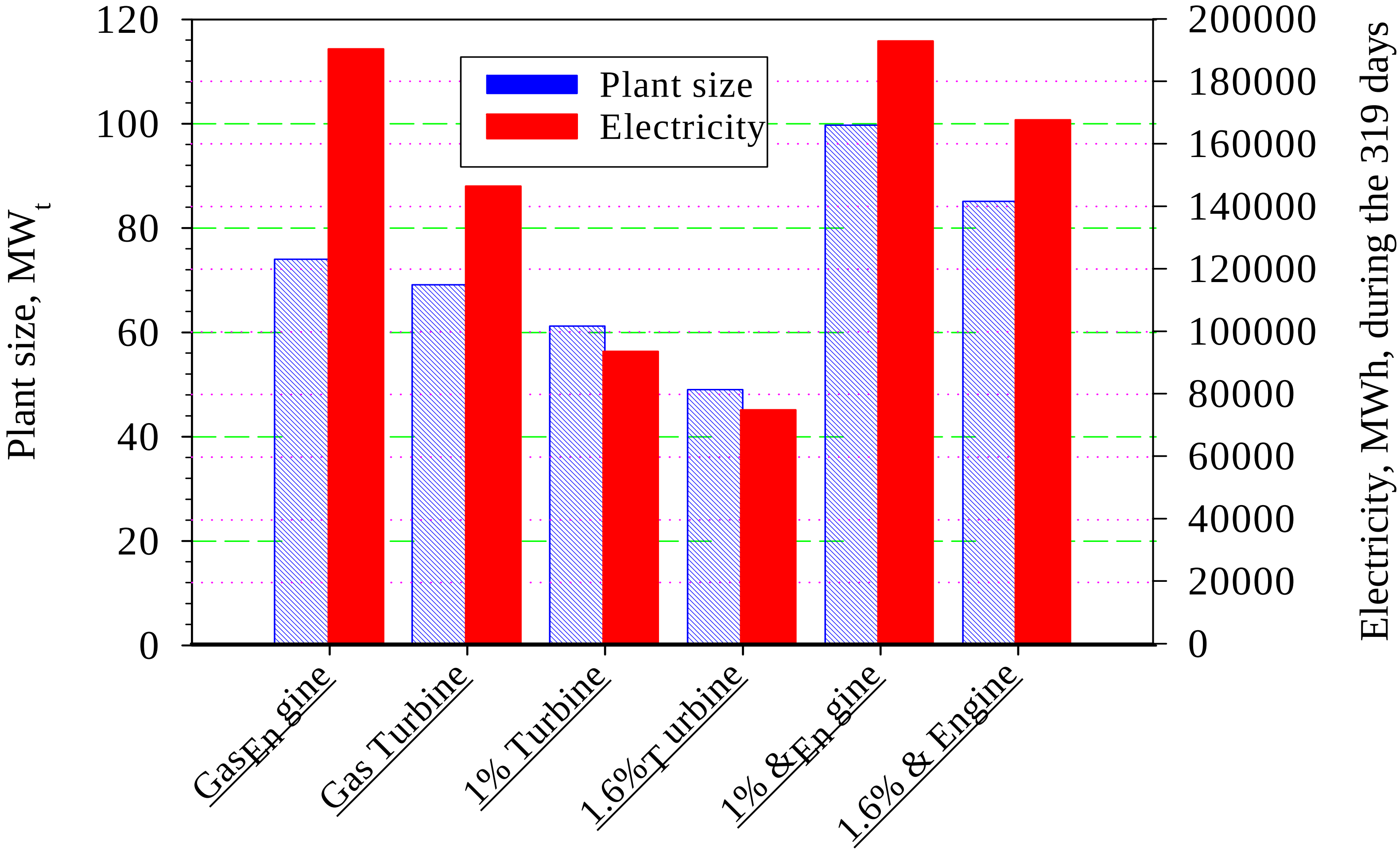
Combined 1% methane turbine and gas engine power plant



CSIRO

Case study-Mine 1

Comparison of plant sizes and electricity production

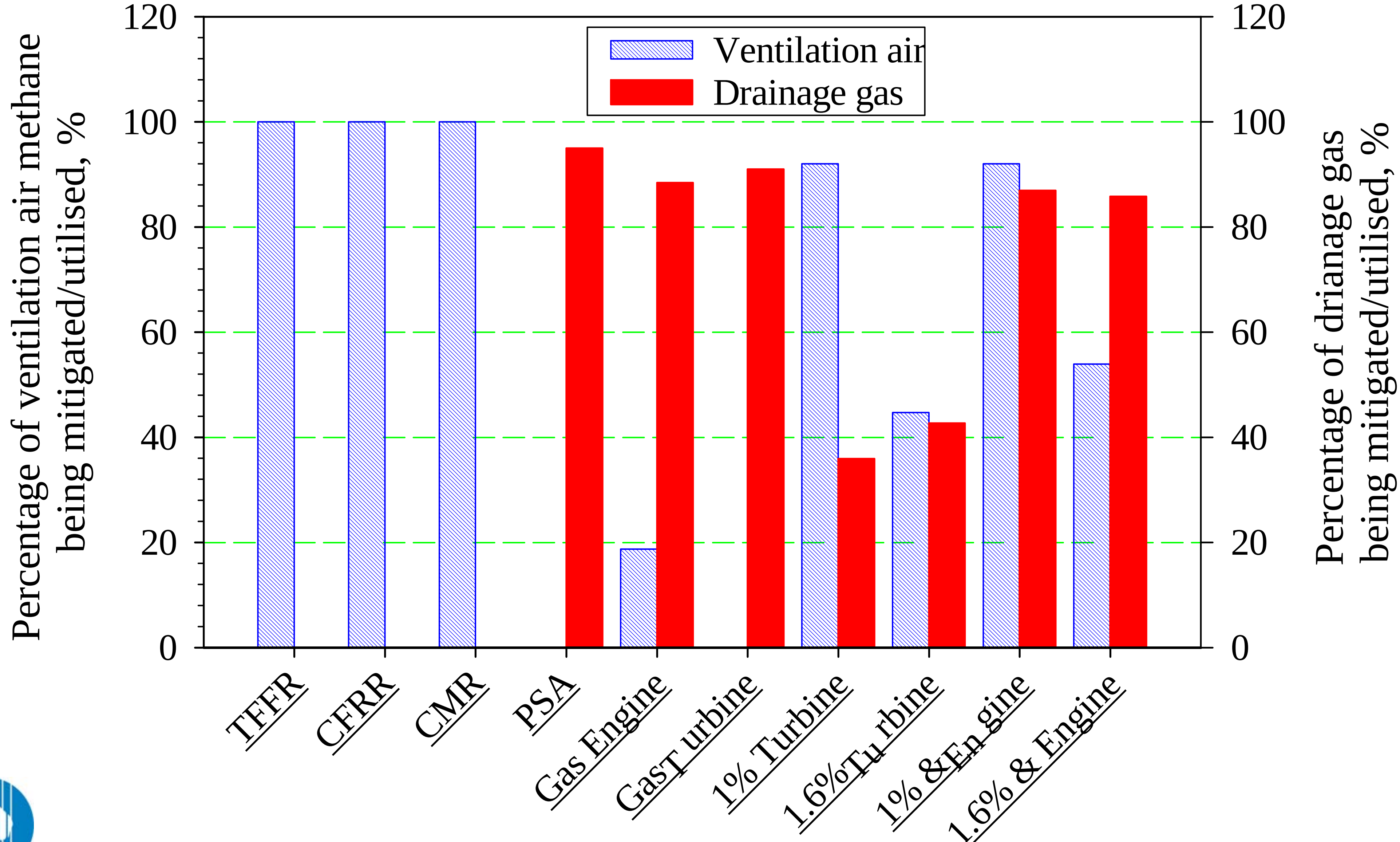


Gas Engine - Gas engine power plant
Gas Turbine - Gas turbine power plant
1% Turbine - 1% CH_4 lean-burn turbine plant
1.6% Turbine - 1.6% CH_4 lean-burn turbine plant
1% & Engine - combined 1% CH_4 lean-burn turbine and gas engine power plant
1.6% & Engine - combined 1.6% CH_4 lean-burn turbine and gas engine power plant

CSIRO

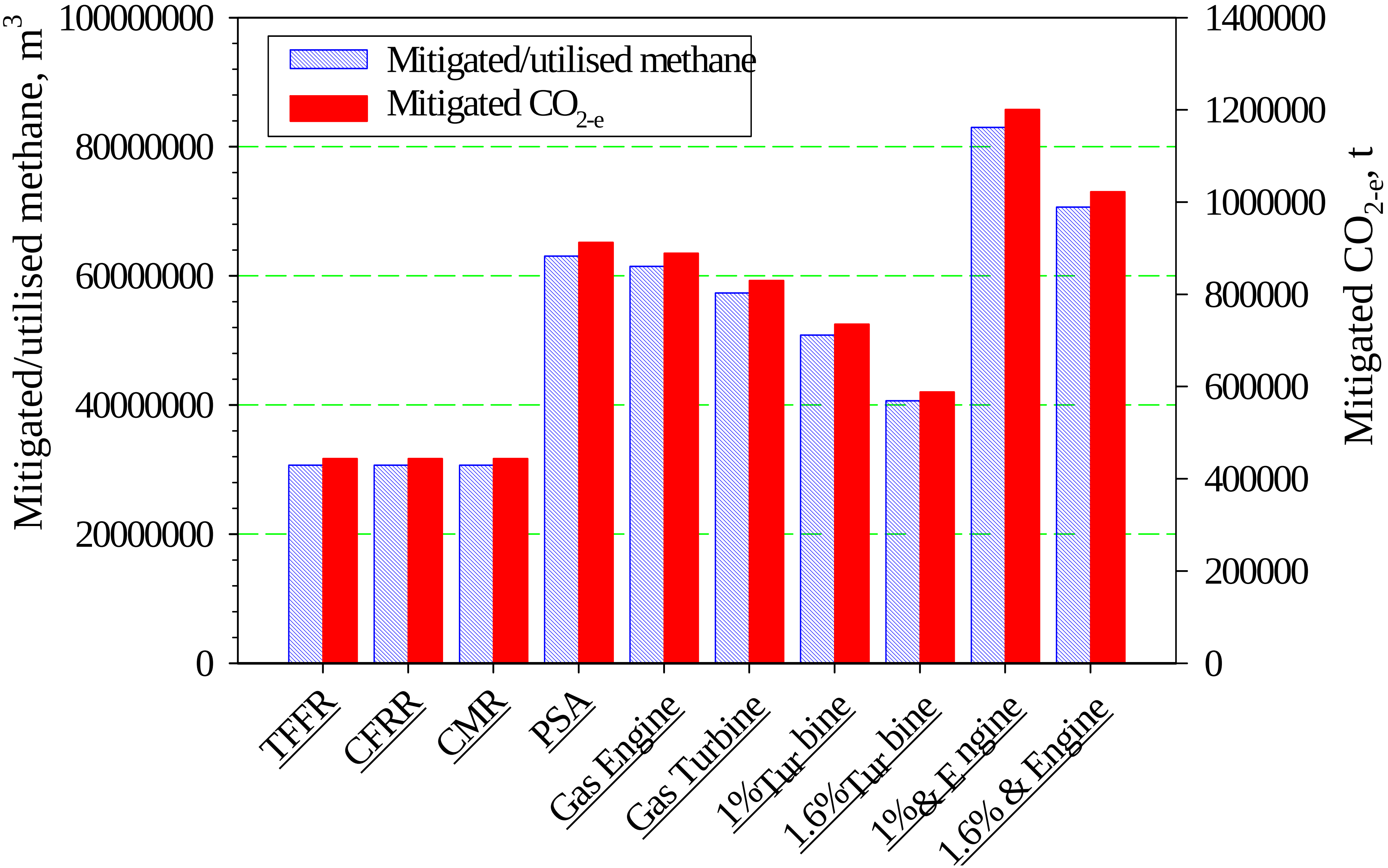
Case study-Mine 1

Comparison of methane mitigation and utilisation



Case study-Mine 1

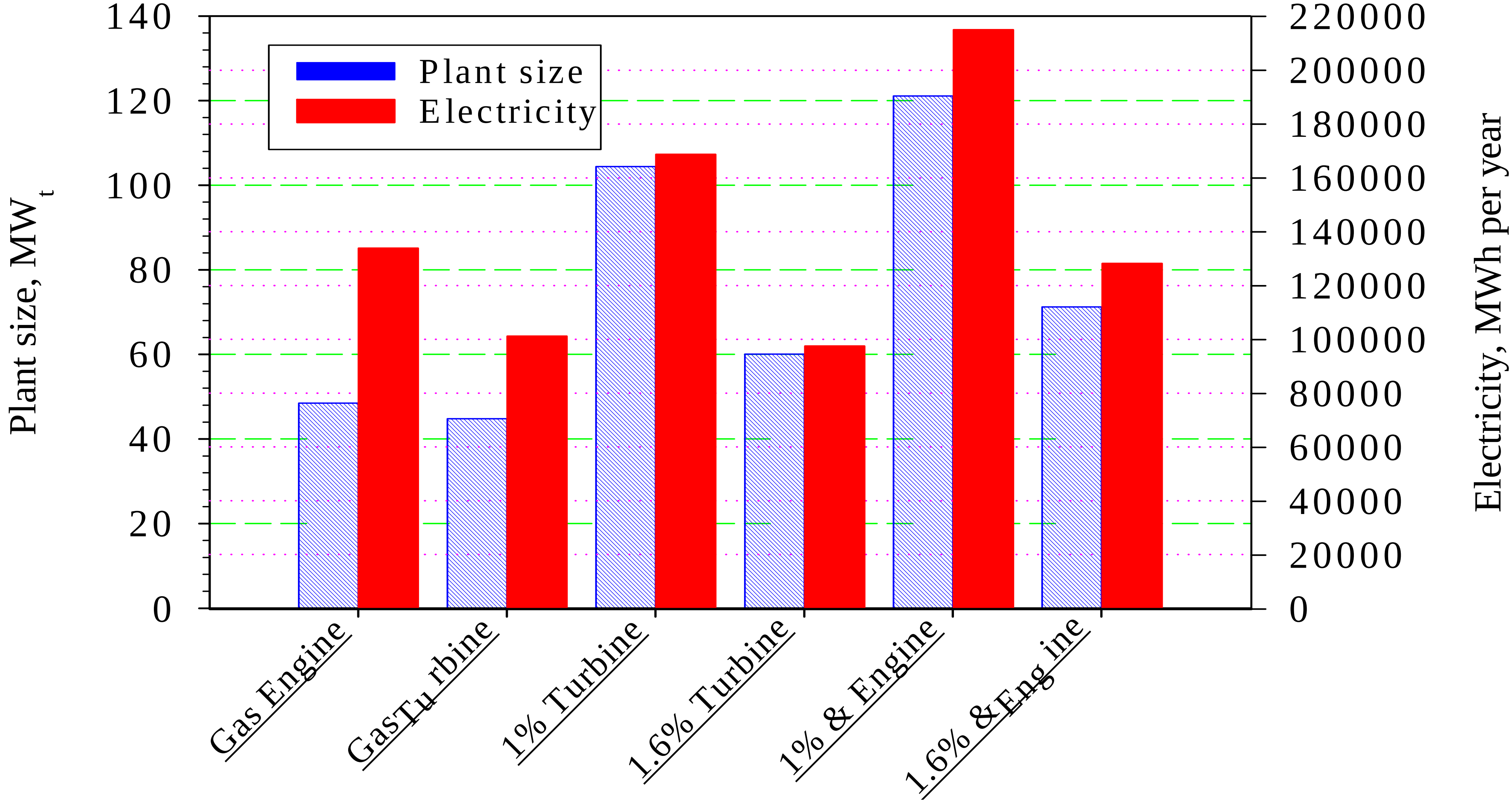
Amount of mitigated/utilised mine methane



❑ Case study-Mine 2 (Typical gassy mine)

✓ ~64% CH_4 emitted with ventilation air

✓Analysis summary of plant size and electricity production



Potential of the 1% CH_4 turbine for ventilation air methane at typical gassy mines!

❑Mine methane mitigation and policies

Applications in Australia

- ❖National Greenhouse Strategy – framework
- ❖National Carbon Accounting System – publishes data
- ❖Greenhouse Abatement Program – provides capital

  German Creek, Teralba, Bellambi mines (gas engines)

  West Cliff (TFRR – MEGTEC)

- ❖NSW Greenhouse Abatement Certificates NGAC

  Credits are owned by owner of facility that does the mitigation example – Kiln with waste coal & mine methane

- ❖National renewable scheme – mine wastes excluded although municipal waste methane included

❑Current research projects in CSIRO

- *Characterisation and cleaning of mine ventilation air flows (Shi Su),*
- *Technical and economic issues on mine methane mitigation and utilisation (Shi Su),*
- *Development of a small pilot-scale demonstration unit of 1% CH_4 catalytic turbine (Shi Su),*
- *International networking on greenhouse gas (CH_4) mitigation (Shi Su),*
- *Coal mine greenhouse gas measurement – Australian practice (John Carras),*
- *Monitoring methane emissions from open cut mining (John Carras).*

CSIRO

In CLOSING

Before a successful deployment of any technology, the following important issues need to be resolved:

- *is the technology proven?*
- *no decrease in mine safety and compliance with all regulatory standards,*
- *profitable economics using the methane energy and carbon reduction revenues,*
- *who owns ventilation air methane/CMM,*
- *units have to be portable.*