# The context

*Escalating electricity cost is one of the biggest cost drivers in the mining industry.*

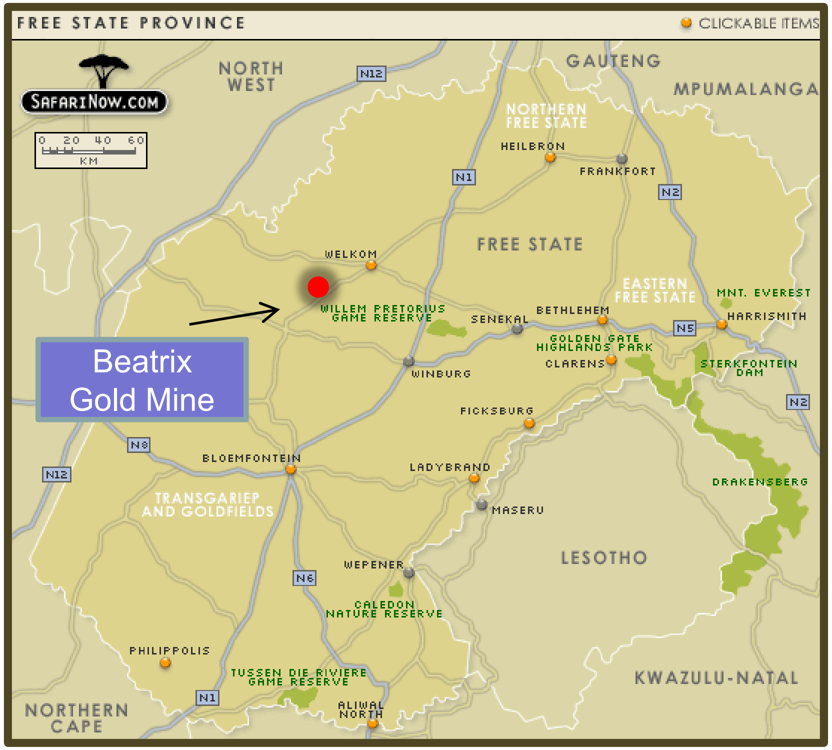
*Safety and health is of paramount importance and cannot be compromised to accommodate electricity cost savings.*

*With careful planning, changes to current ventilation and refrigeration systems can result in major electricity cost savings, while maintaining impeccable safety and health standards.*

# Introduction

- Reasons
  - Electricity costs increase can result in pre-mature closure of underground operations
  - Ventilation to standard concept must ensure uncompromised safety and health standards
- Case study is of deep level gold mine in South Africa with:
  - Present, two and five year life of mine plans considered
- The mine operations can be described as:
  - Four operational areas at up to 2300 m below surface
  - Features sub-vertical shaft
  - Majority of production from 19 to 21 Levels
  - Poor ground conditions resulting in closed or restricted airways

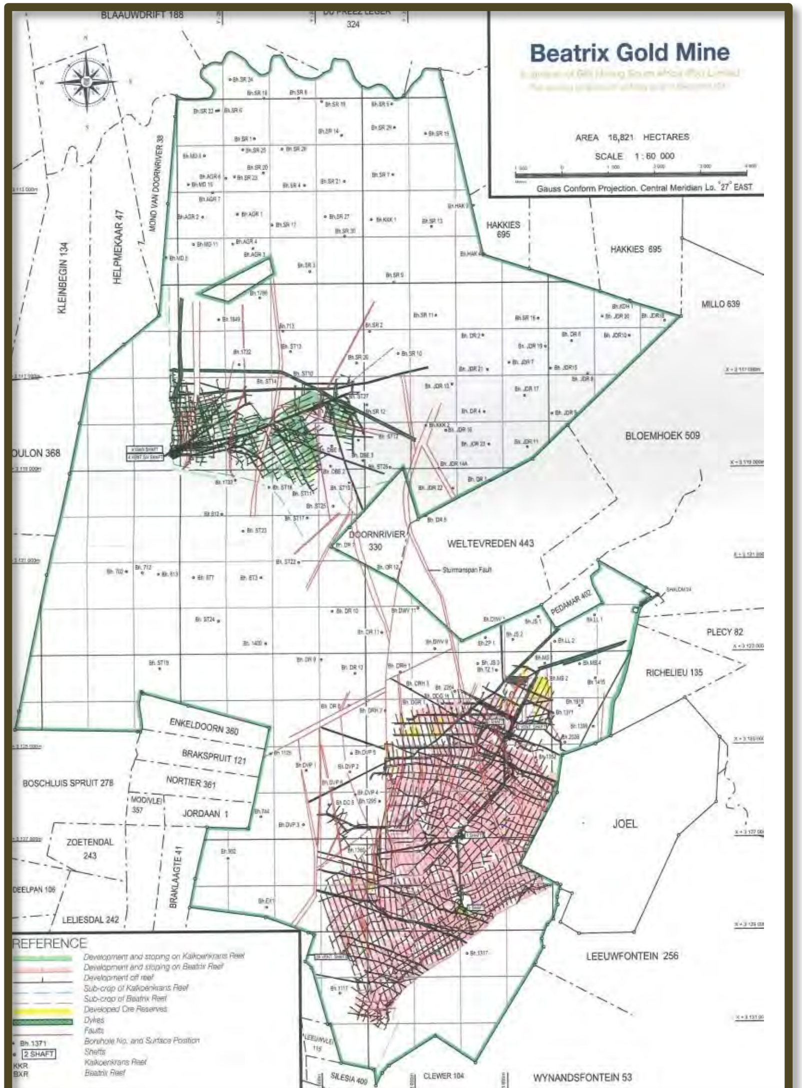
# Position of Beatrix Gold Mine





Located in the Free State Province of South Africa
280 km South of the city of Johannesburg
40 km South of the city of Welkom

# Background




Main complex:
Three operating shafts

West Section:
17 km North of the Main Complex

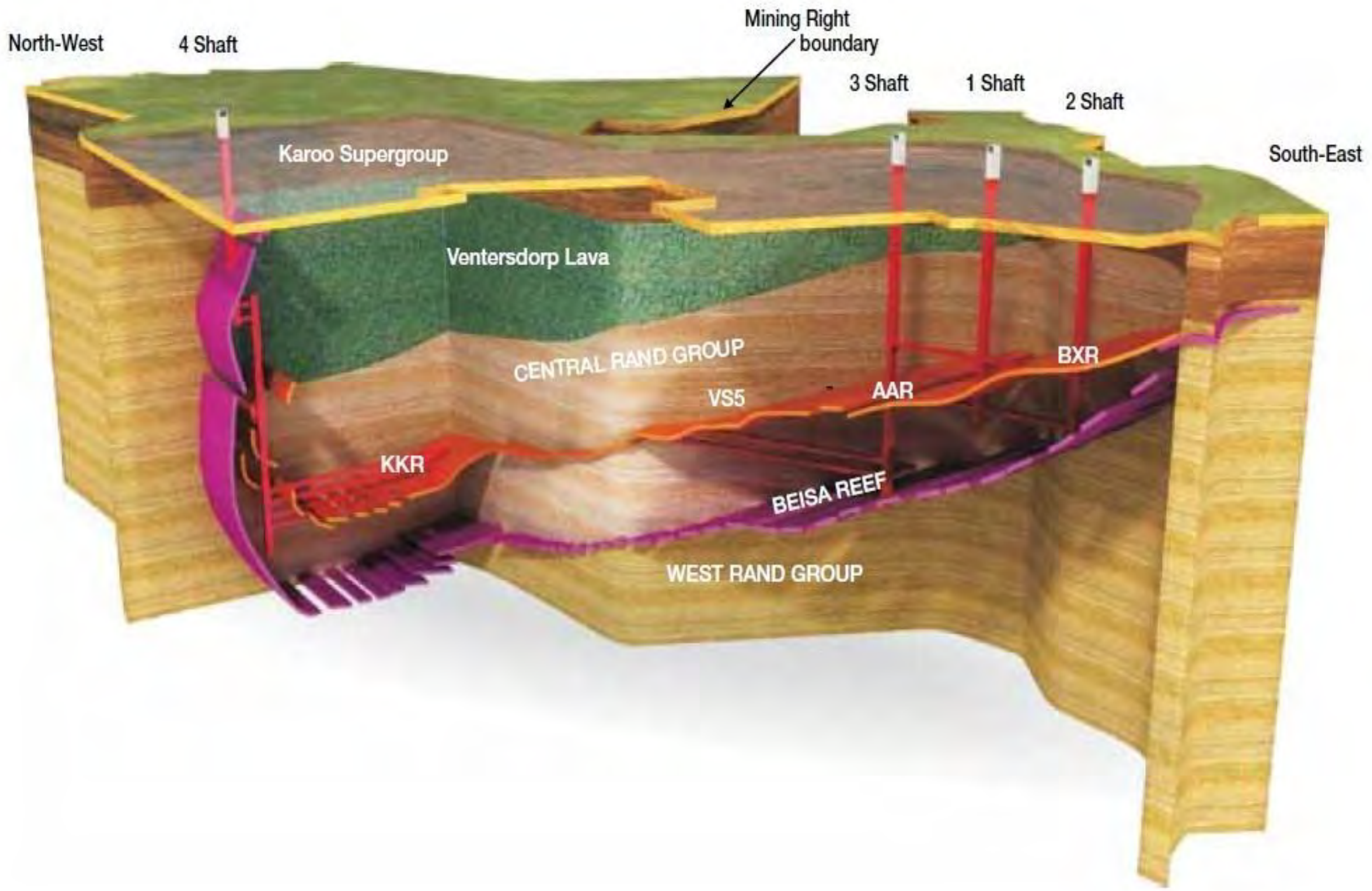
Rock breaking depth:
866 m – 2036 m

Production rate:
225 000 tonnes/month

Total mass flow:
1826 kg/s

Refrigeration:
60 MW

# Mine schematic section



# Methodology

- Follow do's and don'ts of Deepmine and Futuremine Research Programmes for system design (optimum ventilation cooling strategies and technologies)
- Develop VUMA 3D Network models
  - Calibrate models
  - Validate models
- Models are then used for simulating
  - Various options and scenarios
  - Predicting Optimised solution based on simulations

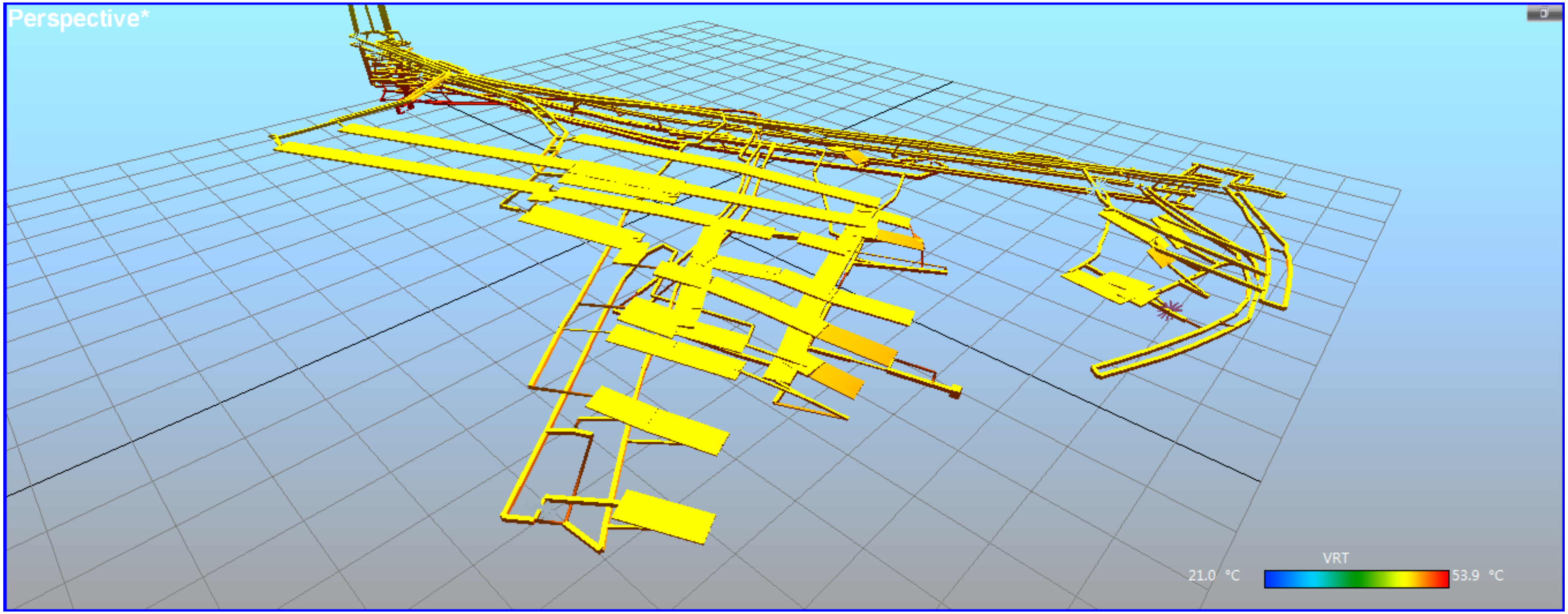
# Goal

- Find most energy efficient system that satisfies design criteria and ensuring or improving healthy and safe workplace conditions

# Software modelling

- Software should accurately simulate rock heat flow including:
  - Dynamic advancing stoping faces, headings, fronts, drifts.
  - Dynamic broken rock for all mining scenarios.
  - Static surrounding rock situations.
  - Braking-rock heat.
- Consider all additional artificial heat sources
- Consider adiabatic heat gains associated with mining at depth
- Software should simultaneously simulate the aerodynamic and thermal environment

# Software modelling



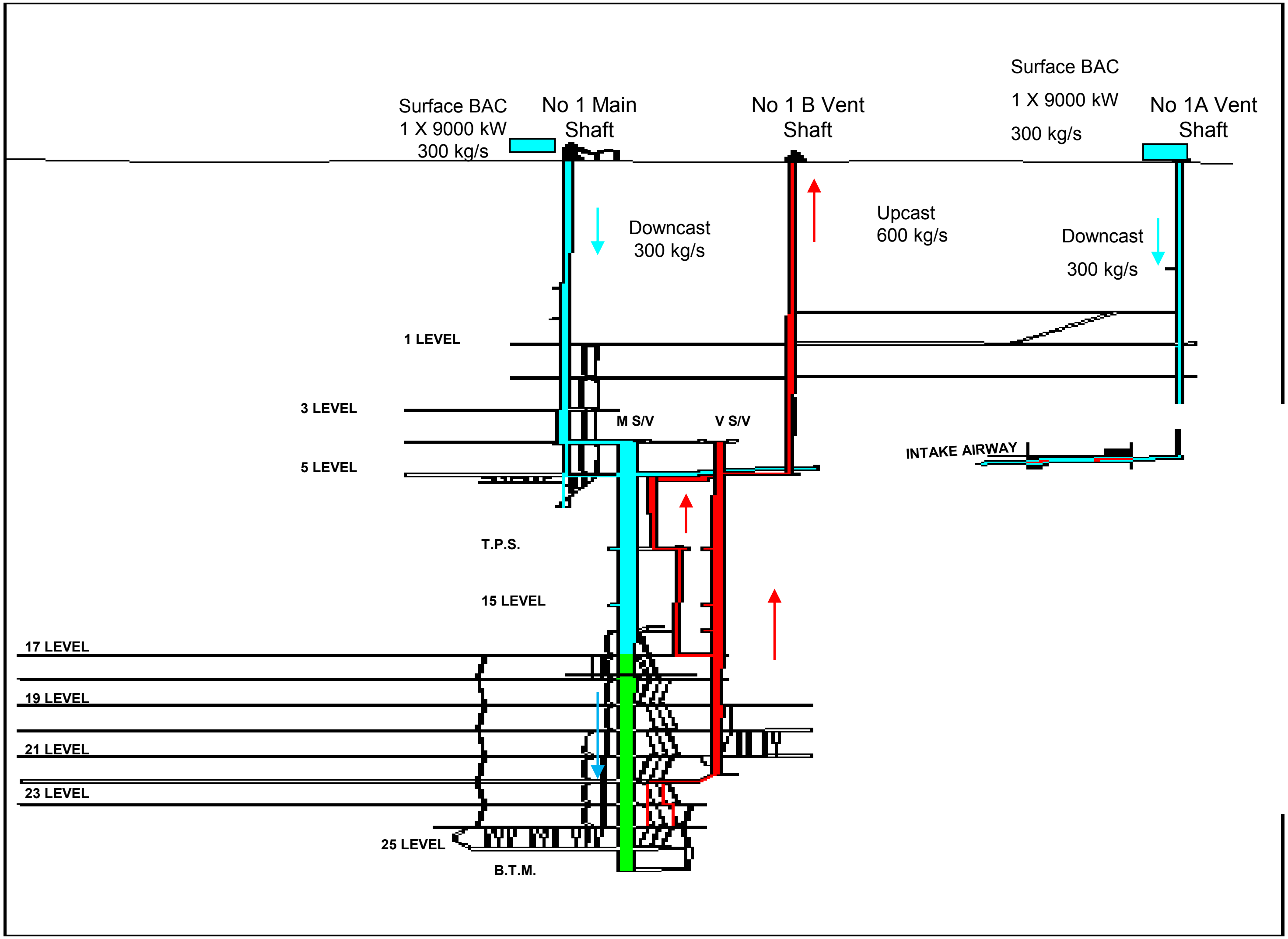
# Design criteria & assumptions

- Minimum of 20 m³/s airflow per stoping line
- Maximum face temperature of 27.5°C wet-bulb
- Surface bulk air coolers to deliver 20 MW[R] of air cooling
- Chilled service water consumption of 3.5 ton of water per ton of rock
- All fans  were assumed to operate efficiently (as per design)
- Future underground cooling water increase by 50 ℓ/s
- Only one of the two installed turbines in each station will operate
- Operational efficiency of turbines at 60 %
- CoP for surface and underground refrigeration plants at 6 and 4
- Return water temperature from underground at 28°C
- All leakages assumed to be sealed off

# Current Ventilation and Cooling

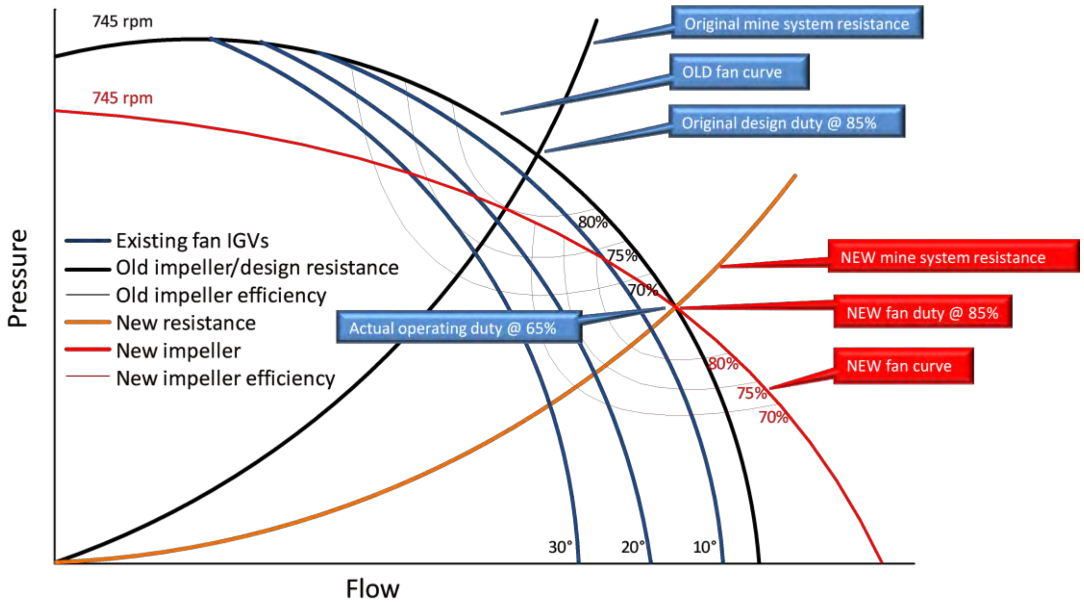
- Two downcast shafts from surface to five level
  - 300 kg/s per downcast shaft
- One up cast shaft handling 600 kg/s
- Booster and auxiliary fans provide ventilation to the extremities
- Strategic raise bore holes to assist with ventilation circulation
- 39 MW ammonia refrigeration plant on surface
  - One 9 MW bulk air cooler per surface downcast shaft
  - Strategic underground bulk air coolers
- Two energy recovery stations
  - Two turbines on 5 level
  - Two turbines on 16 level

# Section of shaft system



# Ventilation options

- Some strategies already investigated and implemented on ***main fans***
  - Inlet guide vane control(implemented)
  - Fan impellor replacement (investigated)



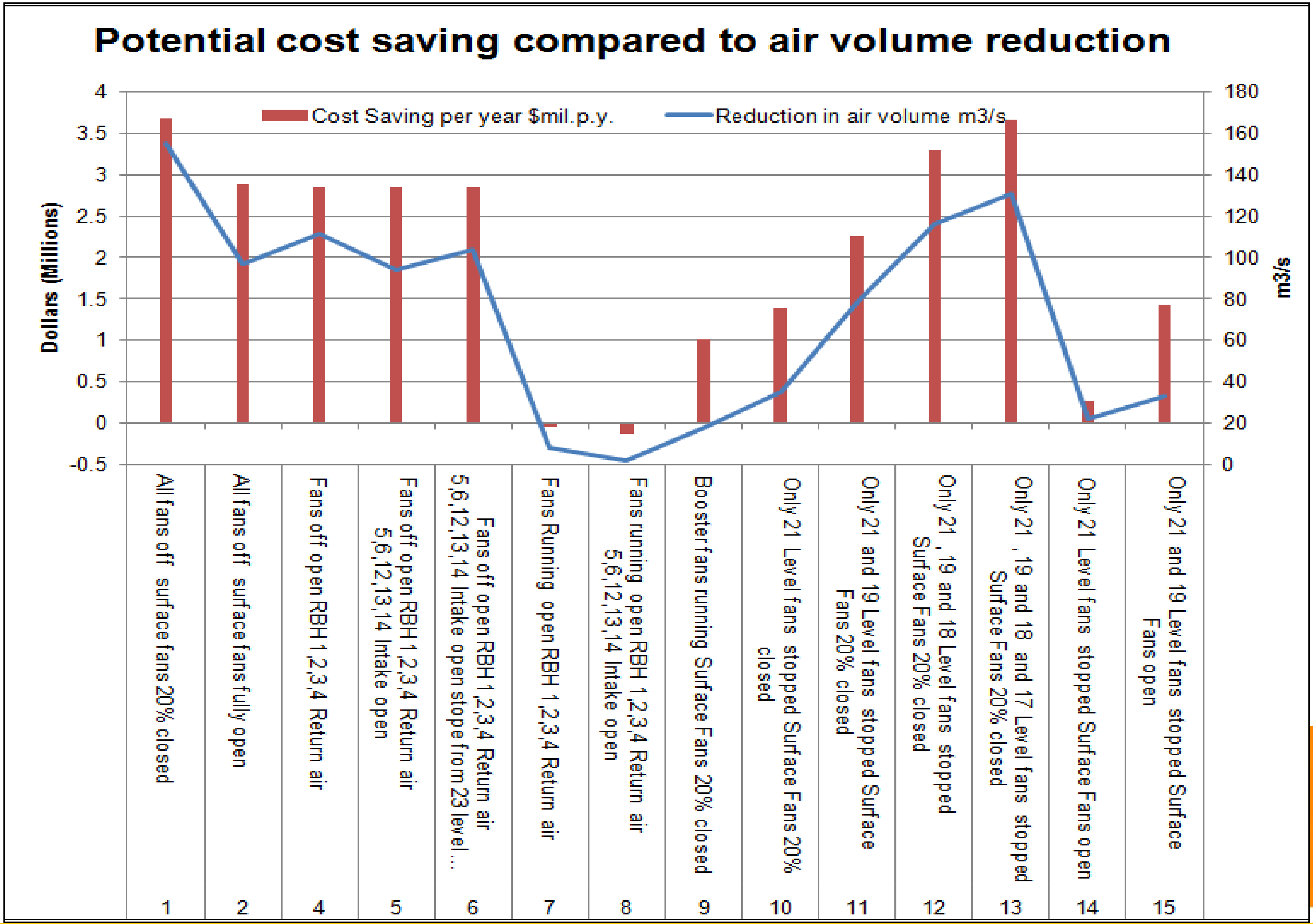

- The following options were considered for ***underground fans***
  - Utilisation of existing Raise Bore Holes (RBHs) by opening up seals.
  - Reduction of the number of booster fans.
  - Provision of a practical and cost effective return air system utilising existing combinations of booster fans and raise bore holes.

# Results – Ventilation Scenarios

- RBH options provided little gain [less than 8% change from present]
- Surface & booster fan options considered:
  - Surface fans **20% closed** IGVs, all underground booster fans **stopped**
  - Surface fans **20% closed** IGVs, all underground booster fans **running**
  - Surface fans **20% closed** IGVs, 21 Level booster fan **stopped**
  - Surface fans **20% closed** IGVs, 21 and 19 Level booster fans **stopped**
  - Surface fans **open IGVs**, all underground booster fans **stopped**
  - Surface fans **open IGVs**, 21 Level booster fan **stopped**
  - Surface fans **open IGVs**, 21 and 19 Level booster fans **stopped**

Note: Surface fans most efficient with 20% closed IGVs

# Results - Ventilation



# Results - Ventilation

| | | < Fan input Power kW | < Air Volume $m^3/s$ | <Air volume per MW saved | Rank |
|---|---|---|---|---|---|
| 1 | Surface fans 20% IGVs - All booster fans stopped | 3 784 | 155 | 41 | 6 |
| 2 | Surface fans open IGVs - All booster fans stopped | 3 004 | 97 | 32 | 4 |
| 3 | Surface fans 20% IGVs – All booster fans running | 1 191 | 18 | 15 | 1 |
| 4 | **Surface fans 20% IGVs – L21 booster stopped** | 1 564 | 35 | 22 | 3 |
| 5 | Surface fans 20% IGVs – L21+L19 booster stopped | 2 407 | 79 | 33 | 5 |
| 6 | Surface fans open IGVs – L21 booster stopped | 476 | 22 | 46 | 7 |
| 7 | Surface fans open IGVs – L21+L19 booster stopped | 1 597 | 33 | 20 | 2 |

Reduction in fan absorbed power and air volume

Notes:

- Scenario 3 was ranked first
- Scenarios 4 and 7 offer additional power savings
- Scenarios 1, 2 and 5 – offer larger reductions in power but not recommended due to potential Health and Safety considerations

# Potential Cost Savings - Ventilation

- Surface fans with 20% closed IGVs (Scenario 3 )
    - Saving of ±US$1 million per year.
- Scenario 4 was recommended
    - Additional ± US$0.5 million per year.
        - 20% closed IGVs
        - Level 21 booster fan will be stopped
        - No major risk to ventilation flows
        - No major impact on underground environmental

# Refrigeration options

- Conduct high-level trade-off studies between:
  - Combination of surface ice plant, energy recovery turbines, surface refrigeration, underground refrigeration plant or:
  - Combination of surface and underground plants.

BBE CONSULTING

# Potential Cost Savings - Refrigeration

Scenarios:

- New underground refrigeration plants to provide all the underground cooling requirements
  - Power reduction 5.5 MW[E]
  - Payback 4.6 Years
- Convert part of the surface refrigeration plant to produce ice
  - Expected power reduction 4.5 MW[E]
  - Expected payback 2.5 Years
- Install underground refrigeration plant to provide the additional underground cooling and utilise all four turbines
  - Expected power reduction 3.5 MW[E]
  - Expected payback 2.5 Years

# Takeaway points

- With careful planning changes to current ventilation and refrigeration systems on deep level mines can result in major electricity cost savings, while maintaining safe and healthy conditions.
- Possible for the mine to save US$ 1.0 million per annum by running the main fans at 20% closed IGVs.
- Possible for the mine to save an additional US$ 0.5 million per annum by stopping an underground booster fan.
- Significant saving can be achieved by reducing the cooling water that is pumped from the bottom of the mine to surface.