In-Pit Crushing and Conveying

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AGENDA

1. **Introduction - what is In-Pit Crushing and Conveying (IPCC)?**
2. What does a quarry need from IPCC?
3. Why and when should we consider using it?
4. How do we calculate if it is likely to be of benefit?
5. What are the main RISKS associated with using IPCC
6. Questions!!!

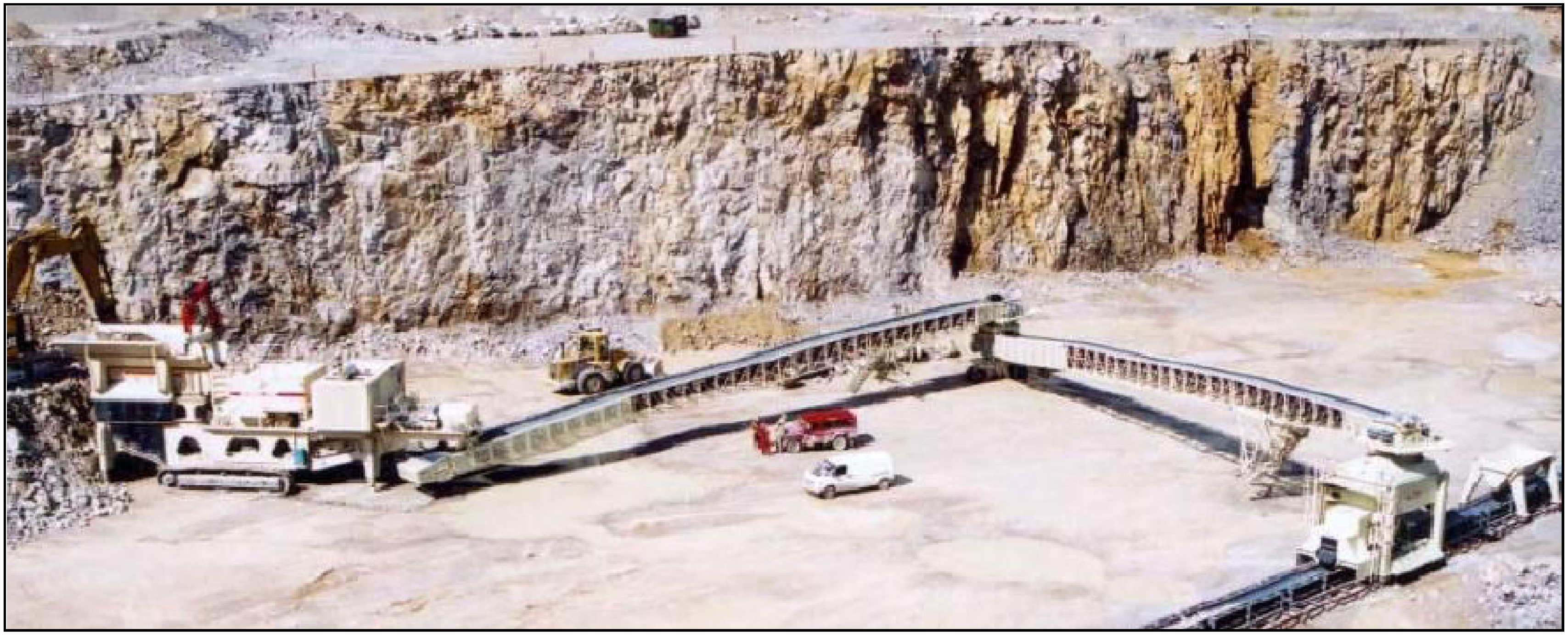
Definition of IPCC

- In–pit Crushing and Conveying or IPCC is the use of **fully mobile**, **semi-mobile** or **fixed** in-pit **crushers** coupled to **conveyors** and **spreaders** (for waste) **or stackers** (for ore) to remove material from an open pit mine.

- It is a means of replacing some or all of the trucks used in a quarry or mine operation

Fully mobile IPCC concept

- Integration of shovel-fed, fully mobile **in-pit** crusher stations
- Conveying of material out of pit and to dumps or secondary process
- Spreading of material at dumps



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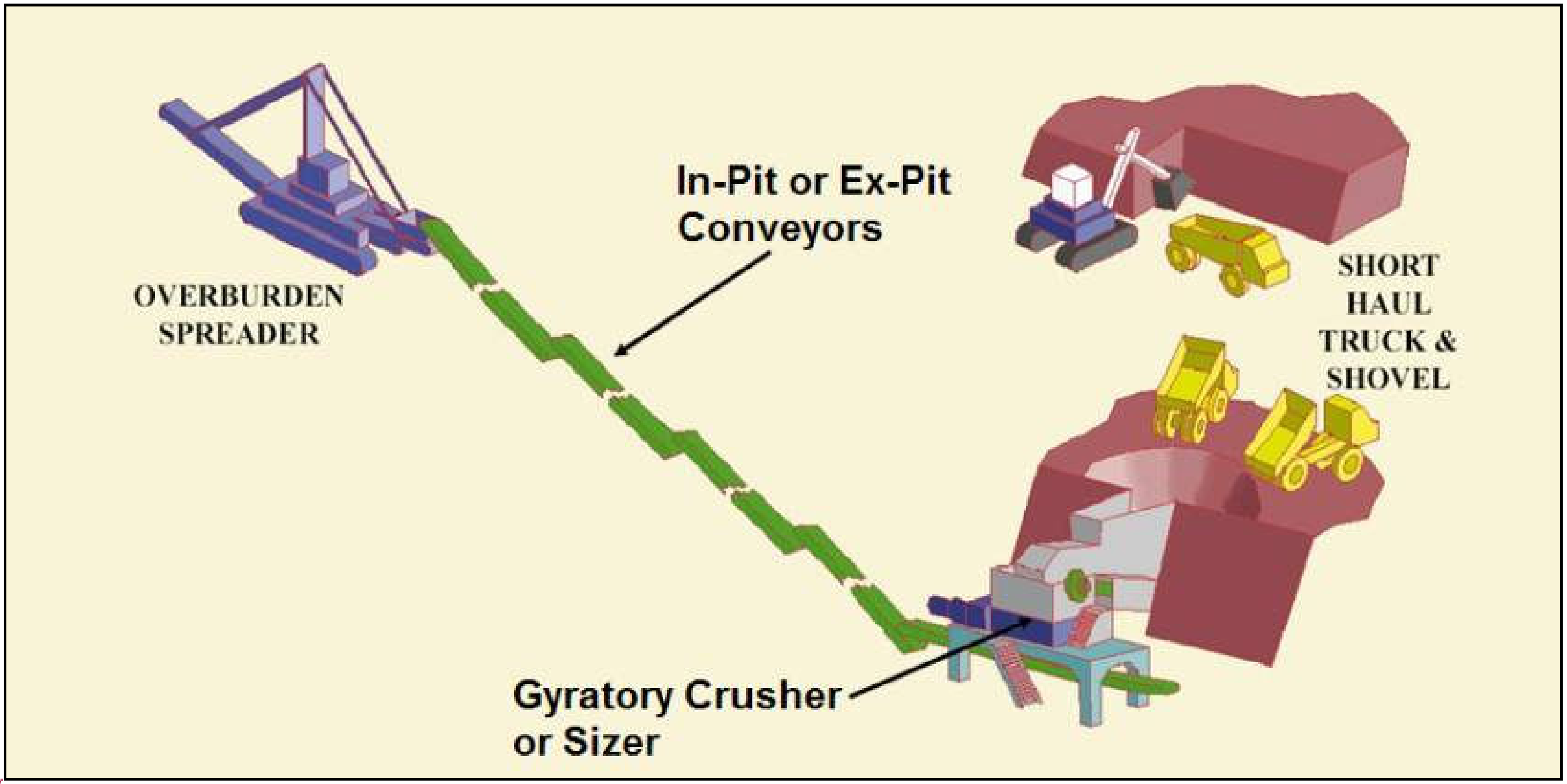
Semi mobile IPCC concept

- Integration of truck-fed, semi-mobile **in-pit** crusher stations
- Conveying of material out of pit and to dumps or secondary process
- Spreading of material at dumps



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Selecting IPCC type

IPCC CRUSHING OPTIONS	FULLY MOBILE	SEMI MOBILE	FIXED
THROUGHPUT	<10,000 t/h	<12,000 t/h	<12,000 t/h
TRUCK QUANTITY	None	Low	Intermediate
CRUSHER TYPE	Sizers, jaw/double roll crushers	Any	Any
UNIT CRUSHING COSTS	Higher	Intermediate	Lower

Fully mobile = no trucks, but higher crushing and conveying cost

Semi-mobile = some trucks and lower crushing costs

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HISTORY

Late 70's – Early 80's

Semi-mobile in-pit ORE crushing systems first appeared in large open pit mines.
The first mine was Cyprus Sierrita here in Arizona, follwed by Morenci.
Required large investments and significant down time to relocate them.

During the 90's

Major truck manufacturers developed trucks of over 375 stph capacity.
These significantly reduced unit costs of haulage.
World oil prices dropped in real and historical terms to near all-time lows.

These factors, combined with the inflexibility of relocating the crushing stations led to their near-demise except in regions with low electricity costs

Now

Increased mining tonnages, increased oil prices, a shortage of tires and qualified operators, and concern over emissions have resulted in a renewed interest in IPCC in WASTE movement.

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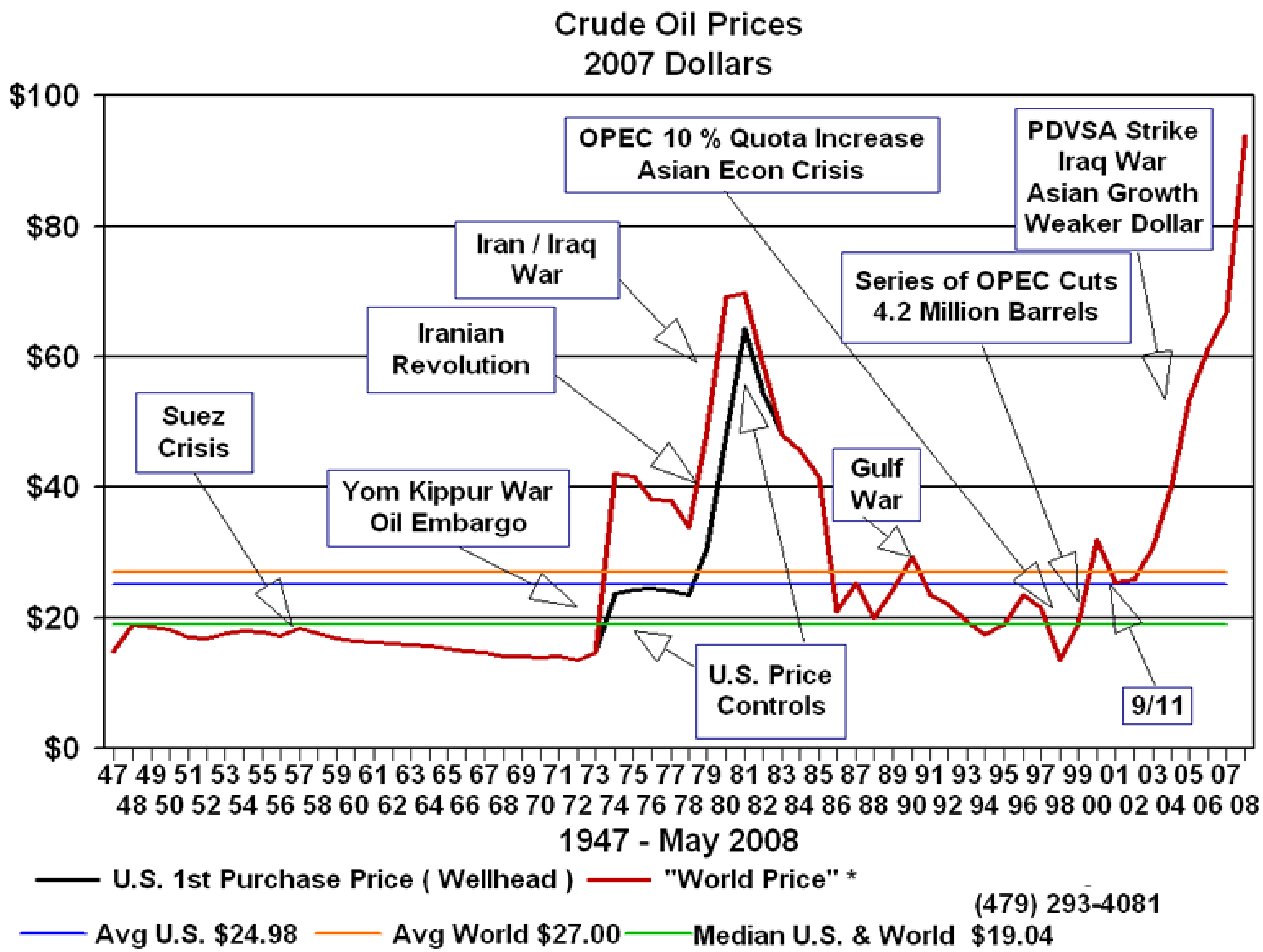

Emissions

The Question of Emissions:

- It is important not to underestimate the importance of the current environmental debate regarding global warming. Major corporations are now revising their corporate objectives to include minimization of their “carbon footprint”.

For Example:

- A typical large (375 stph) haul truck consumes on average up to 70 gallons of fuel per hour.
- This equates to 1500lbs of carbon emission per hour as CO_2,or as much as 4,500tons per year!! [McKinsey, Sandvik Study 2007]
- This adds up to 4 cents per ton mined if a carbon trading scheme prices CO_2 at $30/tonne

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What are typical quarry needs for IPCC?

- Fully mobile crushing units typically up to a maximum of 2,000tph
- Product sizing from primary crushing <150mm
- Minimum generation of fines
- Dealing primarily with “ore” rather than overburden or “waste”
- Short conveyors that can link to a trunk conveyor
- Cross-pit or overland conveyor to a processing (secondary crushing and screening) plant

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Key questions to ask when considering IPCC for quarries

1. **How long is the quarry life?**
   - Need probably 5 years to pay back capital and +10 is ideal
2. **What are the material movements?**
   - Probably need at least 1mtpa (say 300tph for 3300hrs a year)
3. **Are electricity costs low? Are diesel fuel prices high?**
   - Electricity price ($/kwh) less than 25% of diesel price ($/l) (or 10% of the price per gallon) helps if you can run an electric unit rather than diesel powered
4. **How many material types?**
   - Don't want to have to convey to multiple locations as conveyors are expensive
5. **Are rock strengths low?**
   - If < 70MPa then use of sizers or double rolls crushers (DRC) makes IPCC cheaper in both capital and operating costs but new hybrid DRC can process up to 150MPa

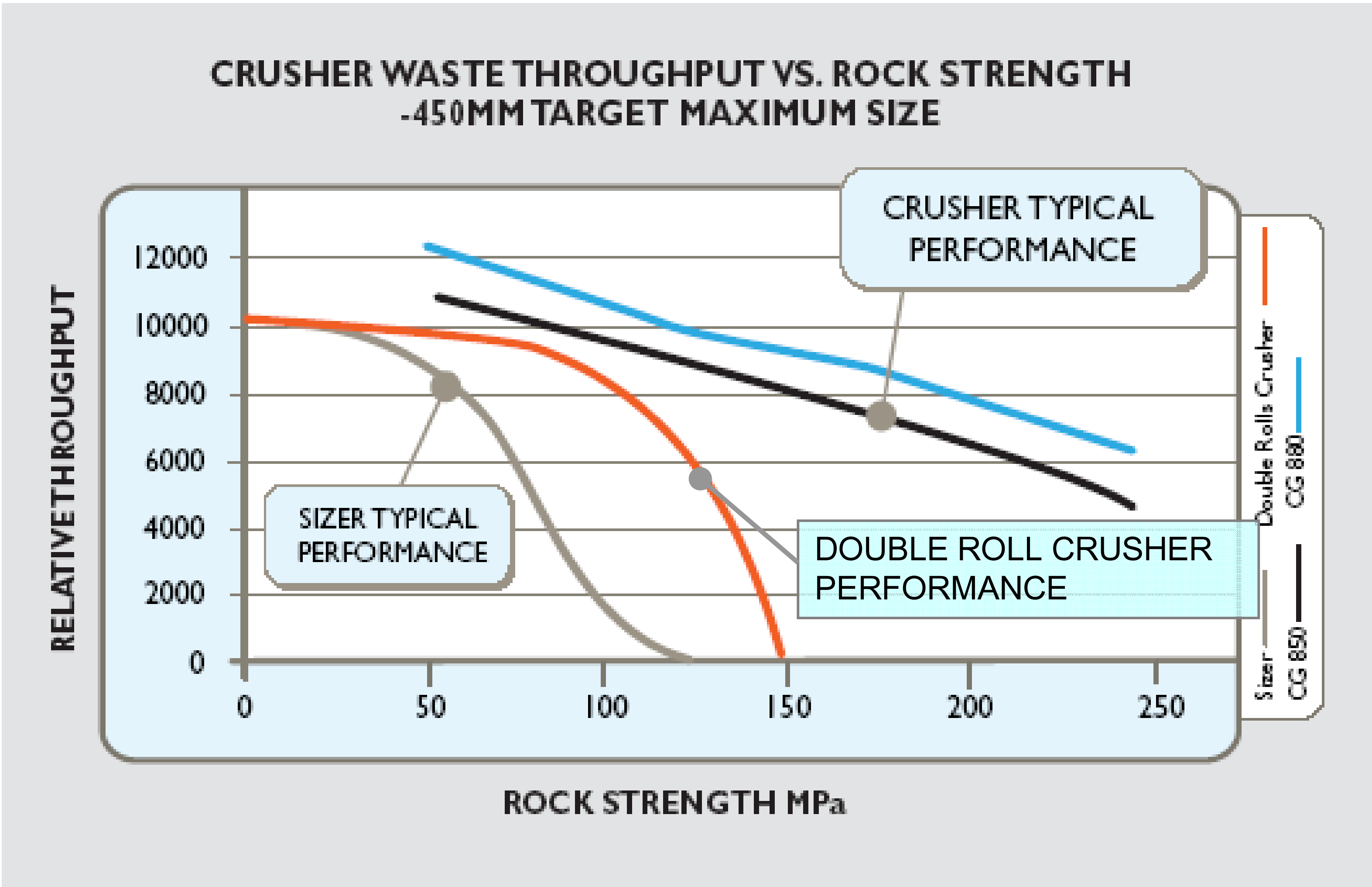
Key questions to ask when considering IPCC cont’

6. **Do you have plenty of space on the quarry floor?**
   - Need to avoid frequent relocation of conveyors
7. **Is there a planned expansion case?**
   - IPCC is generally easier to justify at either the start of a new quarry or when an expansion is planned
8. **How critical is it to keep manning to a minimum?**
   - Due to either cost or shortage or both (at average 2.5 persons per truck saved under IPCC for single shift operation, or up to 6.5 for 24 hr operation)
9. **Planned downhill runs?**
   - Conveyors can generate power on longer downhill runs, but some capital investment is needed.
10. **Is automation of interest?**
    - IPCC lends itself to easy automation
11. **What are existing or planned truck cycle times?**
    - If less than 20 minutes, then IPCC may not work well for you

Rock strengths

What are the rock strengths? Why should we care?

- It is important to understand the relationship between crusher (or sizer), throughput and rock strength.
- It is only possible to achieve "rated" capacities of throughput in low strength and well broken material.
- Please bear in mind for materials with lower strengths, the use of sizers will keep both capital and operating costs down.



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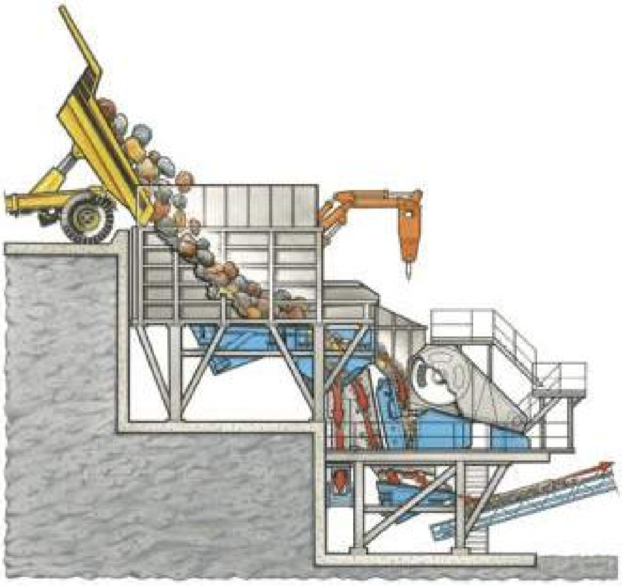

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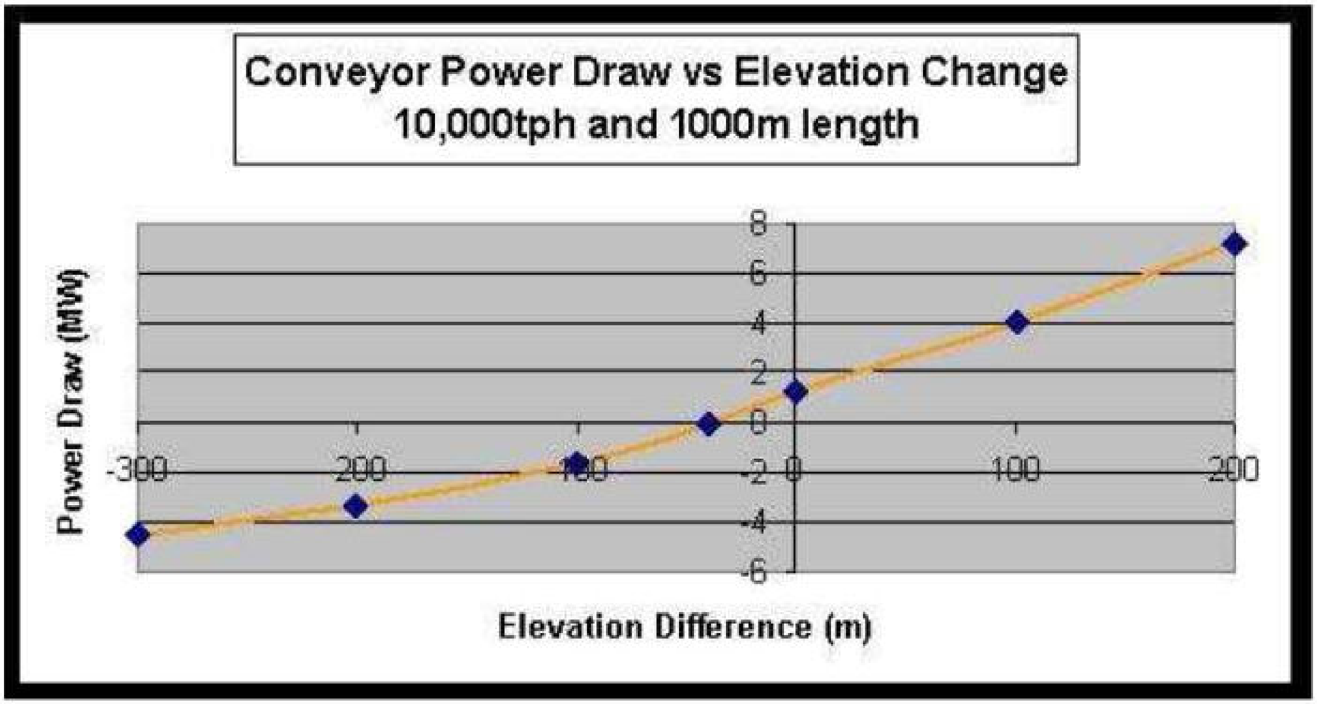
Power

Power is important as IPCC systems need it to run, and if reticulated power rather than on-board power is available than this generally helps IPCC to be more economic.

- Typical operating power requirements for crushing stations and spreaders obviously vary according to the tonnages being handled per hour, the material density and rock strength, and the specific configuration.
- As an indication, however, a “typical” 10,000 stph crushing station might need ~2.0MW of power, and a 12,500 stph tripper car and spreader ~1.6MW.

Power

Figure 7 – Power Requirements versus Elevation Change (m)



This shows that if we have downhill hauls, then **regardless of scale** a conveyor can generate power and offset the operating cost of the system

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Methodology of calculating if IPCC can work

- Calculate operating hours per year and basis of operation
- From available rock hardness, abrasiveness data and product tonnage and maximum size, calculate what crusher would be required for the operating hours per year to try and match the excavator and annual requirements.
- Hence determine conveyor dimensions Look at physicals and determine what the physical haul profile will be. Hence calculate both the cycle time for trucking, the number and size of trucks needed, and also the lengths of conveyor required.
- Calculate total power consumption required, truck operating costs, and labour costs
- Carry out an operating cost comparison
- Incorporate capital for trucks and IPCC and add to operating cost comparison.

Haul distances and cycle times

Haul Distances (m)	A	B
Forward Trip (Loaded):		
Level	1,450	6,750
Up Ramp	50	200
Return Trip (Unloaded):		
Down Ramp	50	200
Level	1,450	6,750
Total Metres	**3,000**	**13,900**

Fuel burn and truck savings

Fuel Burn (litres)	**A**	**B**
Litres/Cycle	**31.1**	**142.6**
Litres/Hour	**382.1**	**380.3**
Truck hours per year (operating)	8,676	39,933
Fuel saved @30Mtpa Kl	19,225	106,307
Truck reductions	1.3	6.2

Yes these are big trucks, but the principle applies to smaller operations!

Hauling cost estimation

	A	B
Truck Cost/Hr	528.3	527.0
Truck cycles per hour	12.28	2.67
Fuel burn per year (kl)	3,315	15,187
Cost per dry tonne hauled	**0.153**	**0.701**

This shows the impact of the haul distance on the cost of hauling

IPCC operating cost estimation

	A	B
IPCC Crushing cost/t	0.00	0.00
Power - 150m Ramp	0.00	0.00
Power - 500m fixed	0	0
Power - ramp 10%	0.012	0.048
Power - Flat overland	0.028	0.130
Power - Spreader	0	0
Opcost - 150m Ramp	0	0
Opost - 500m Fixed	0	0
Opcost - 200m Ramp	0	0
Opcost - Flat overland	0.019	0.048
Opcost - Spreader 24ktph	0	0
Total IPCC Cost est	**0.059**	**0.226**

Note no crushing cost here as this is common to both truck and IPCC options

IPCC operating cost estimation

	A		B	
Net unit cost saving (transport) =	$	0.094	$	0.476
Annual saving =	$	2.818	$	14.277
Pit ore mtonnes (dry) =		50		50
Total estimated saving =	$	4.7	$	23.8
Conveyor Capital spend $m =	$	3.0	$	15.0

Note that for this tonnage the operating cost saving is not much larger than the capital cost. More tons equals more savings!

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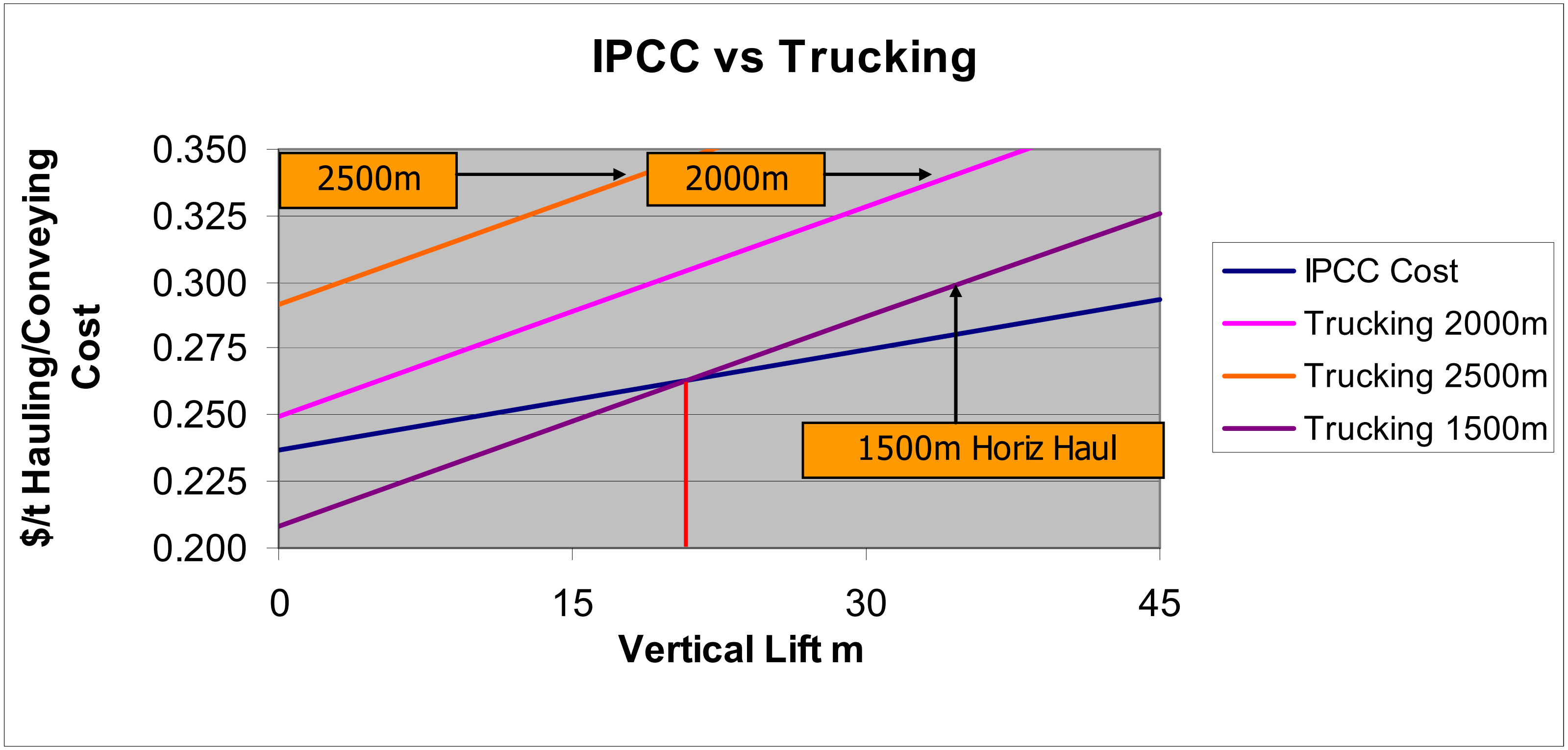
Trucking versus conveying cost



1. This graph shows when IPCC starts to produce lower operating costs versus truck haulage with horizontal haul distance ex-pit.
2. For this project the minimum ex-pit truck waste haul was 1500m.

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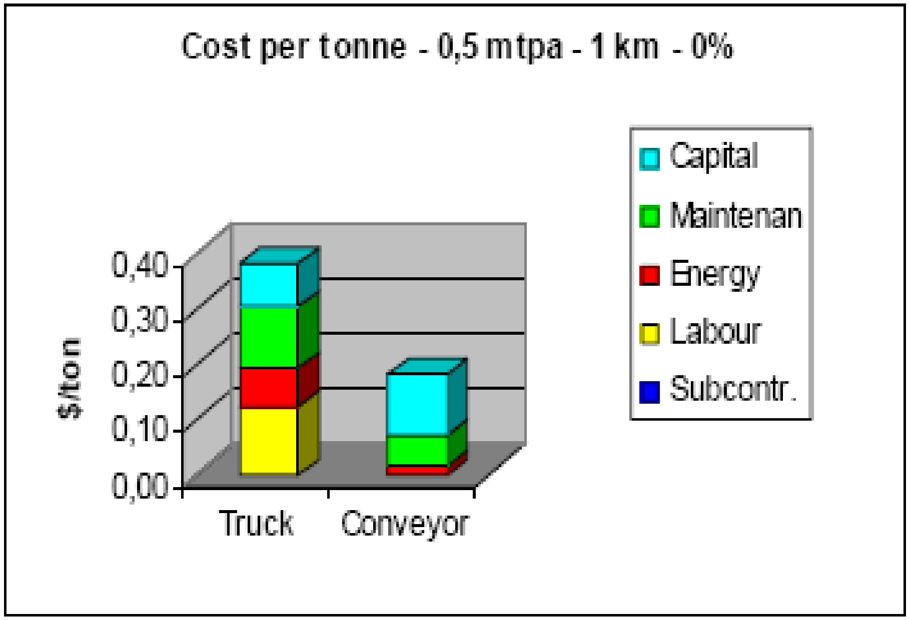
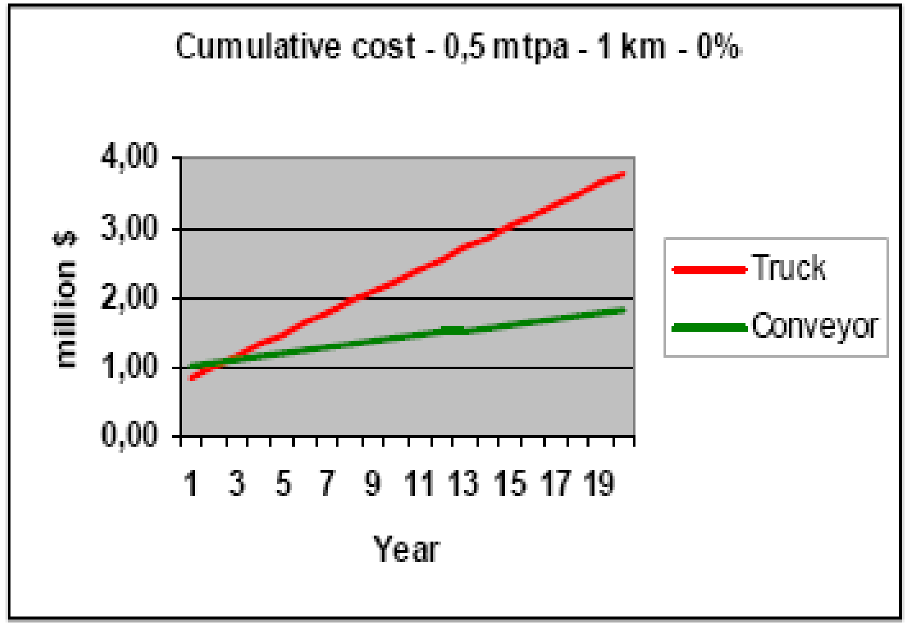
Net Present Value Calculation

	A	B
Truck cost $m	$ 1.800	$ 1.800
Truck Saving	1	6
Capital cost $m	$ 3.0	$ 15.0
Total Cash saving $m	$ 4.7	$ 23.8
Number of years	10	10
NPV at 10%	$1.53	$9.47

Note that in this case there is a small benefit for IPCC with a short haul, but a much better one for the long haul.

Hauling vs conveying 0.5mtpa x 1km @0%





Source: Aari Jaakonmäki – Metso Dec 2007

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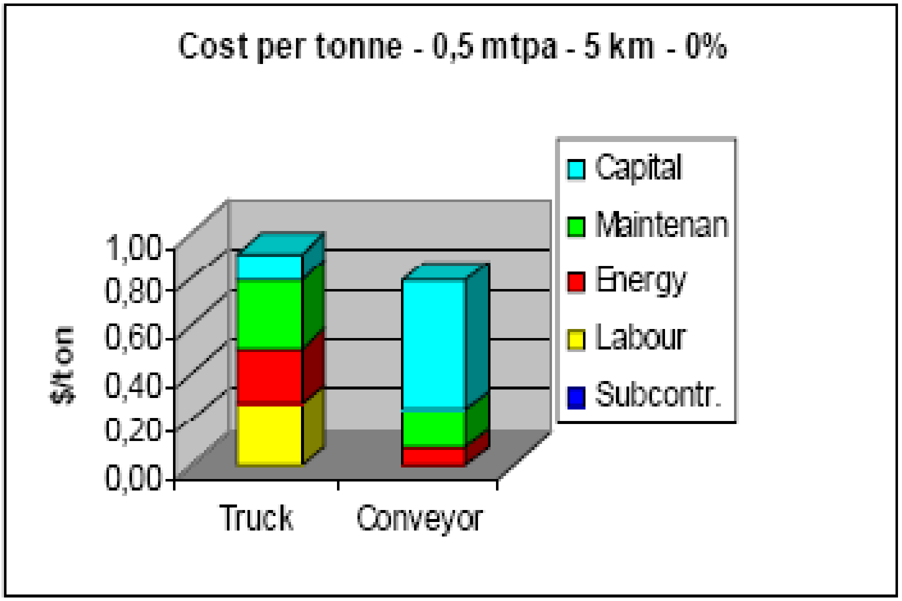
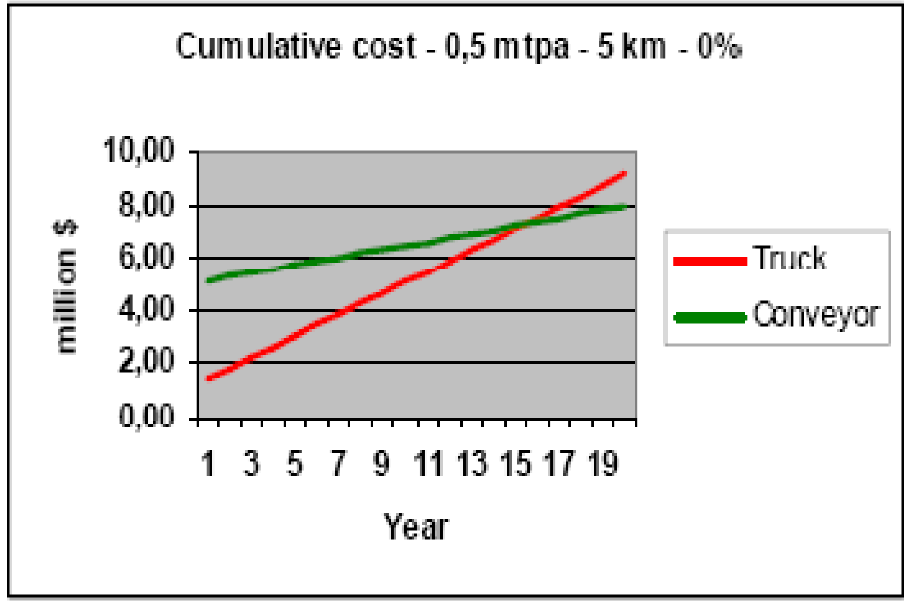
Hauling vs conveying 0.5mtpa x 5km @0%





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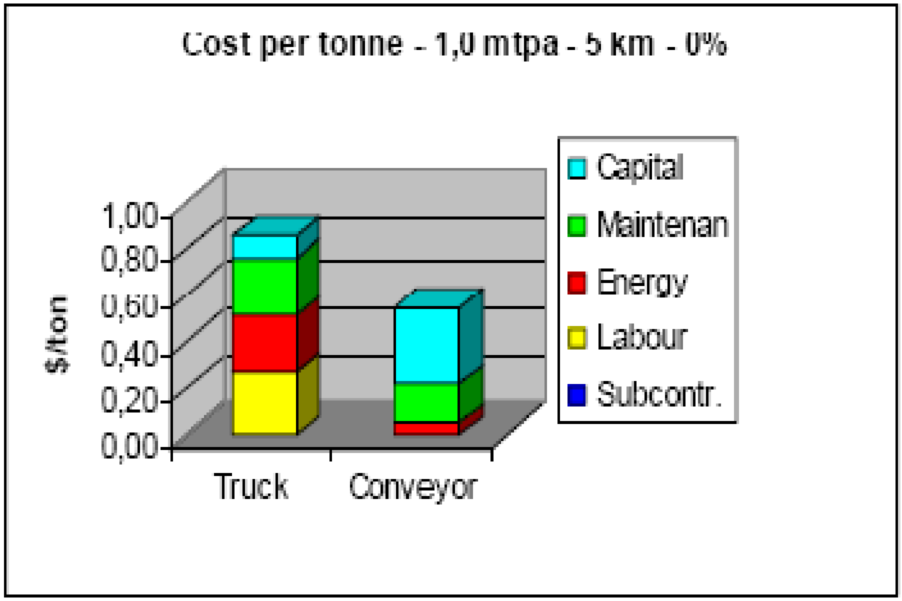
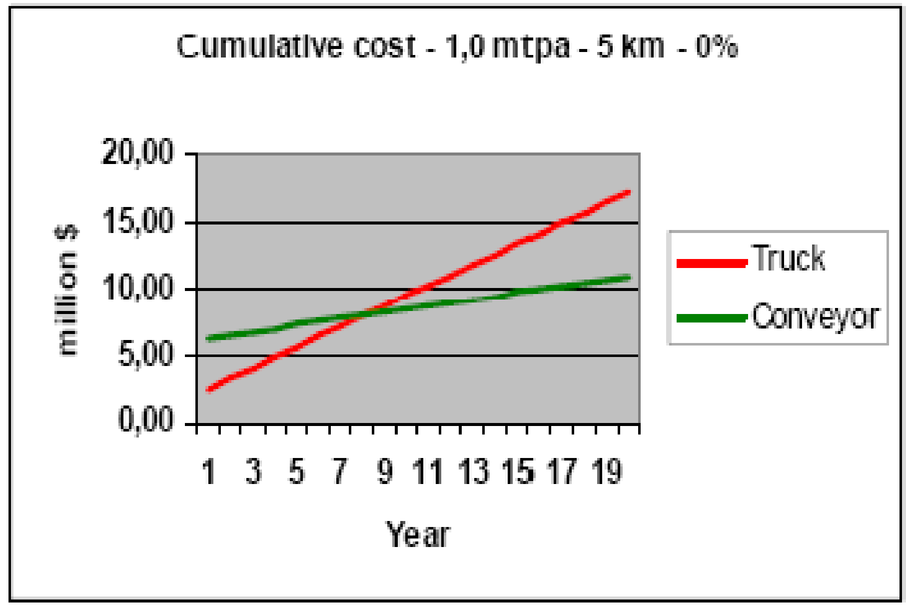
Hauling vs conveying 1.0mtpa x 5km @0%





Source: Aari Jaakonmäki – Metso Dec 2007

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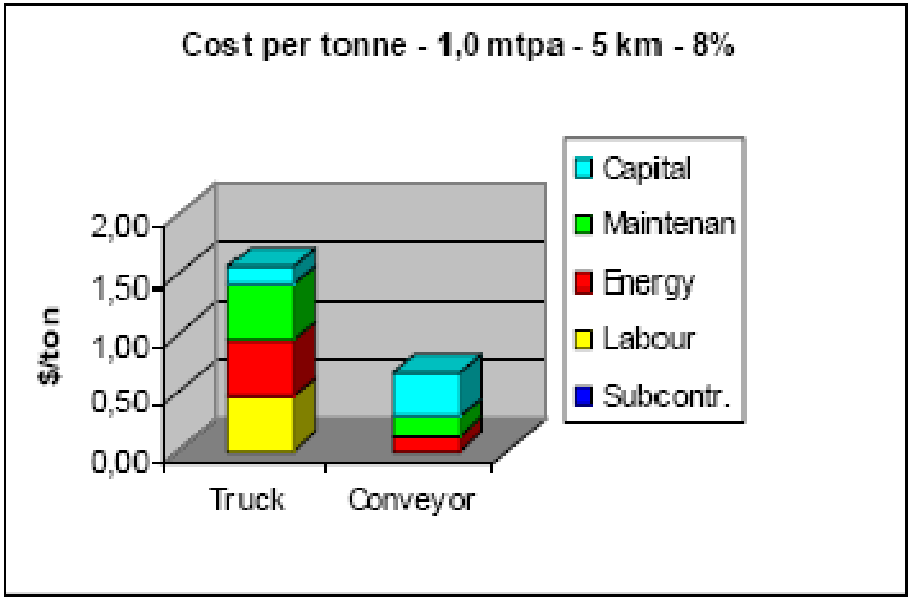
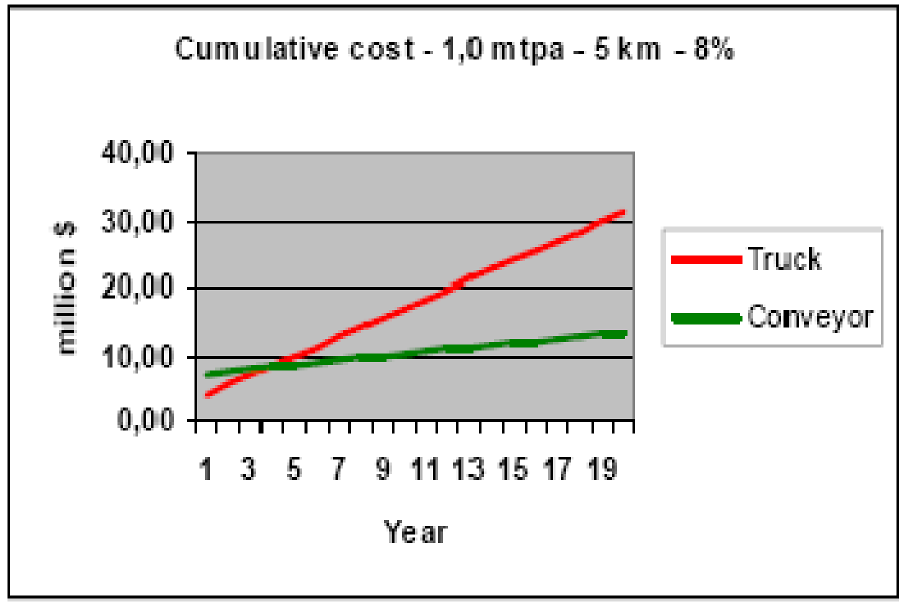
Hauling vs conveying 1.0mtpa x 5km @8%





Source: Aari Jaakonmäki – Metso Dec 2007

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Typical IPCC Study results

MINING STUDIES UNDERTAKEN

- 14 Scoping level studies and 2 PFS level study carried out globally to date (most of these with Alan Cooper doing the mine engineering)
- Minerals include Coal, Copper, Iron Ore, Nickel, Gold, Diamonds and Uranium
- Clients have included Major Mining companies in Latin America, Africa, Canada and Australia
- Throughputs have ranged from 2,500tph to 40,000tph+

RESULTS

- Lowest cash cost reduction achieved: 1 study was not favourable
- Best cash cost reduction US$0.82/t (typical $0.25-0.50)
- Best NPC improvement – +US$800m (@9% discount)
- Typical reduction in manning – averages 6.5 persons per truck saved
- Typical reduction in ancillary equipment – 25 - 30%
- Reduction in infrastructure costs

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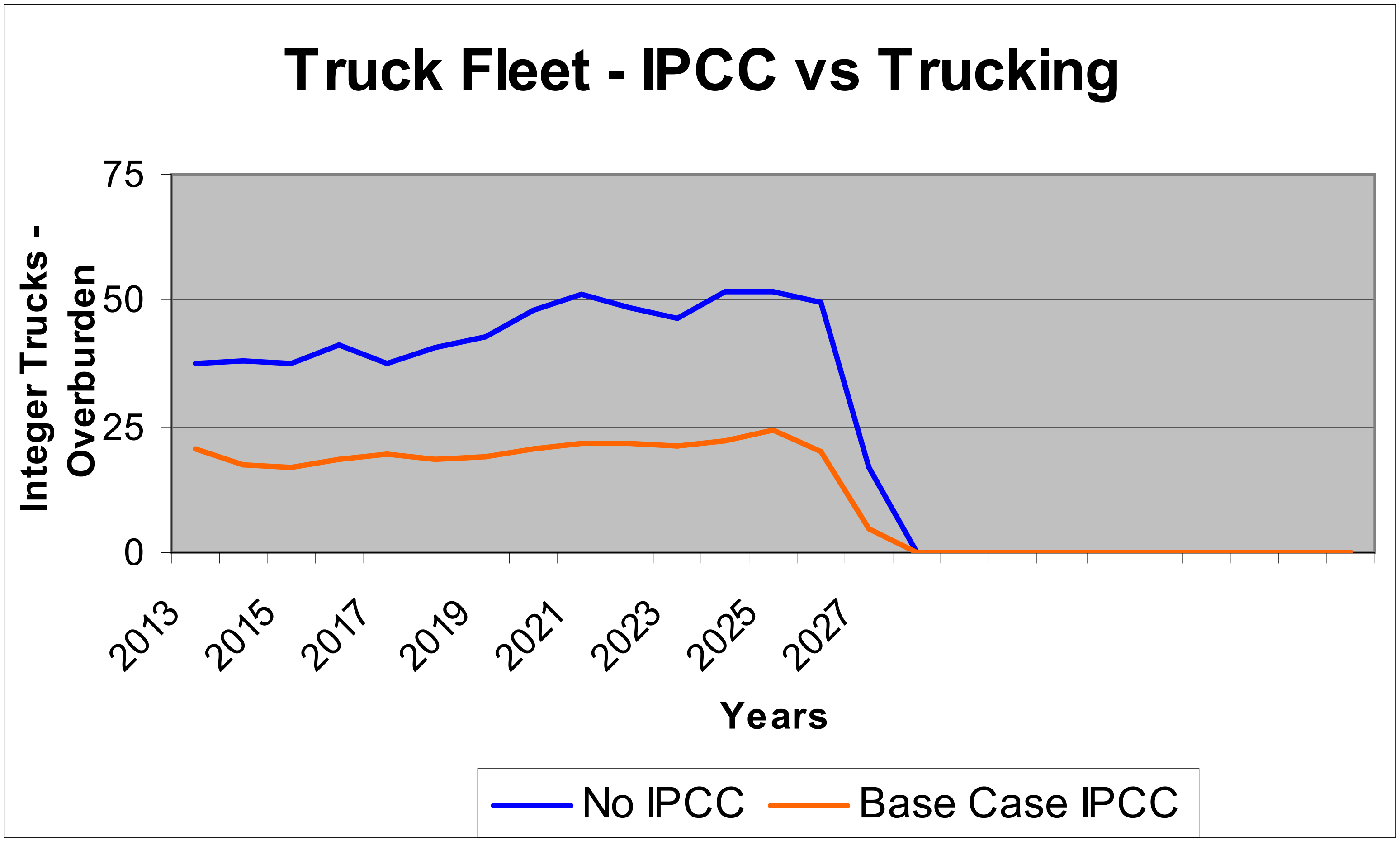
Typical Truck Numbers Hauling vs IPCC



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Typical Capital Cost Hauling vs IPCC

Figure 11 – Initial Capital for Truck/Shovel Case

Initial Capital Equipment	# Units	Total Cost US$m
Electric Drills	4	$ 16.5
Diesel Drills	2	$ 3.4
Electric Shovel 1	4	$ 85.3
Front-end Loader	3	$ 17.8
Trucks 300t	32	$ 139.0
Track Dozer	8	$ 6.8
Wheel Dozer	3	$ 2.0
Motorgrader	4	$ 2.3
Water Truck	3	$ 5.3
Other Equipment	1	$ 9.4
TOTAL		**$ 287.8**

Figure 12 – Comparative Capital for IPCC Case

Initial Capital Equipment	# Units	Total Cost US$m
Electric Drill	4	$ 16.5
Diesel Drill	2	$ 3.4
Electric Shovel 1	4	$ 85.3
Front-end Loader	3	$ 17.8
Truck - 300t ORE	**6**	$ 26.1
Truck - 300t IPCC	**3.5**	$ 15.2
Truck - WASTE Non IPCC	**2.5**	$ 10.9
Track Dozer	**4**	$ 3.4
Wheel Dozer	3	$ 2.0
Motorgrader	**2**	$ 1.1
Water Truck	**2**	$ 3.6
Other Equipment	1	$ 9.4
SUB Total		**$ 194.7**

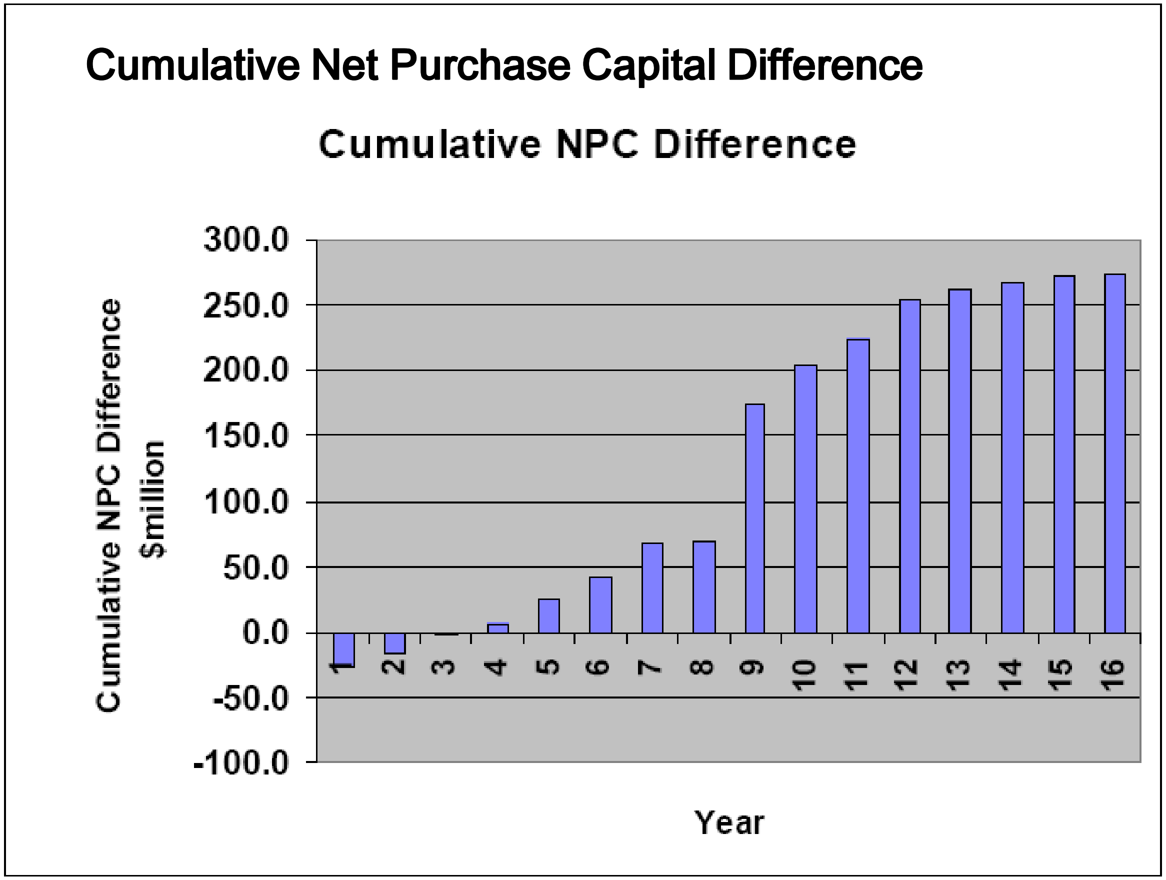
Typical IPCC Capital

Figure 13 – Additional IPCC Equipment Capital

ITEM		Cost US$m
Semi-mobile Sizer 10,000tph	2	$ 57.0
In-pit conveyors @10,000tph	2	$ 16.6
External Fixed Pit Conveyors (2)	2	$ 18.7
Dump Conveyor 20,000tph	1	$ 8.0
Tripper Car + Spreader 20,000tph	1	$ 39.6
Track Shift Dozer	1	$ 0.7
Conveyor Bridges Pit Limit	2	$ 1.0
Transfer Stations (3)	3	$ 3.0
Transporter Unit 450t	1	$ 4.2
Electrical Control Systems	1	$ 1.0
SUB Total		**$ 149.8**
GRAND TOTAL		**$ 344.5**

Typical Payback for IPCC

Figure 14 – Discounted Cashflow Summary



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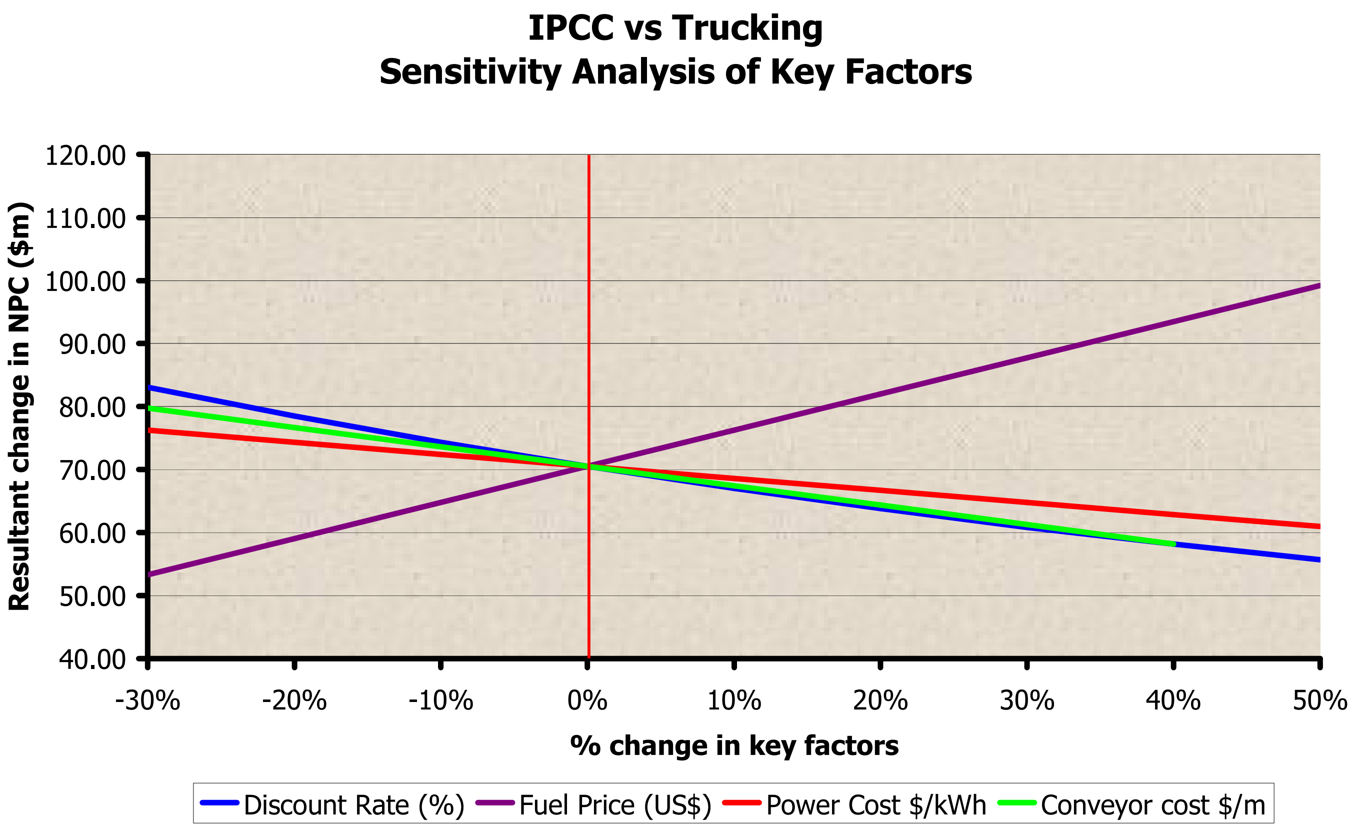
Typical Sensitivity Analysis



Note that this is a typical result where the result is most sensitive to fuel price risk

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6. Questions!!!

Key IPCC risks (from previous studies)

- **Potential for blast damage to IPCC components**
- Lack of understanding of key IPCC planning criteria [flexibility of trucks is often confused with just plane poor planning].
- Failure to achieve operating hours [ability to relocate system in given planned time is critical to success]
- Failure to achieve throughput
- Risk of impact on conveyors by vehicles [risk reduced because of lower vehicle numbers into/out of the quarry]
- Power supply risk [is it available]

Other IPCC negatives

- Time losses during relocation of crushers and conveyors
- Cost of crushing is “dead money” when IPCC is used to replace waste haulage
- Generally not suited to short mine life or low tonnage applications
- Not suited to mine designs with difficult or multiple material destinations for any pit
- Delivery time on IPCC systems and components is long (but not much different to trucks at present time!)

Threats to IPCC success

- A long term decrease in diesel fuel pricing
- Significant electricity price increase during operation
- Significant growth of trolley-assist trucking systems
- Impact of a failure of a spreader or crushing station
- Possibility of further increases to delivery times for IPCC components

DID YOU KNOW ?

That 1 stph of diesel generates 3.2 stph of carbon emissions when burned.

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