Starkey & Associates

Energy Efficiency Comparison in Fine Grinding in the Mining Industry

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Predident

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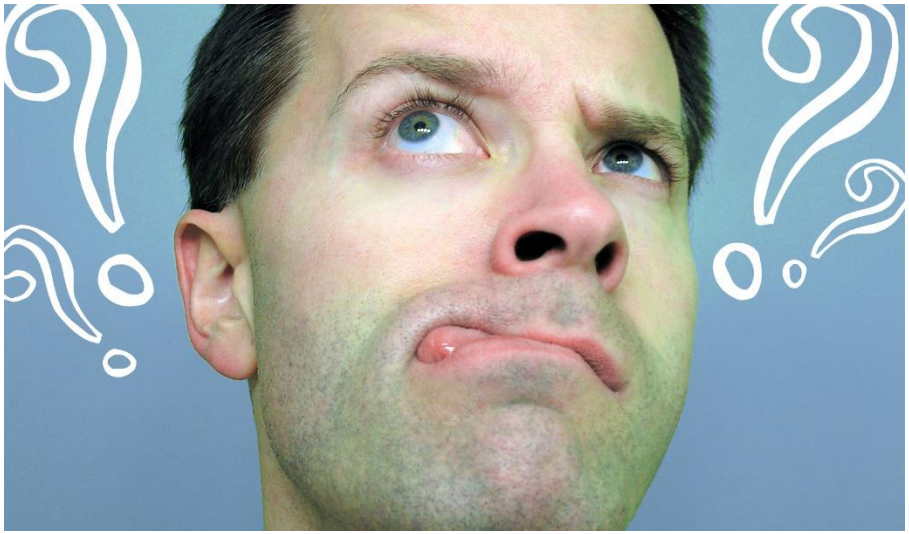
Outline

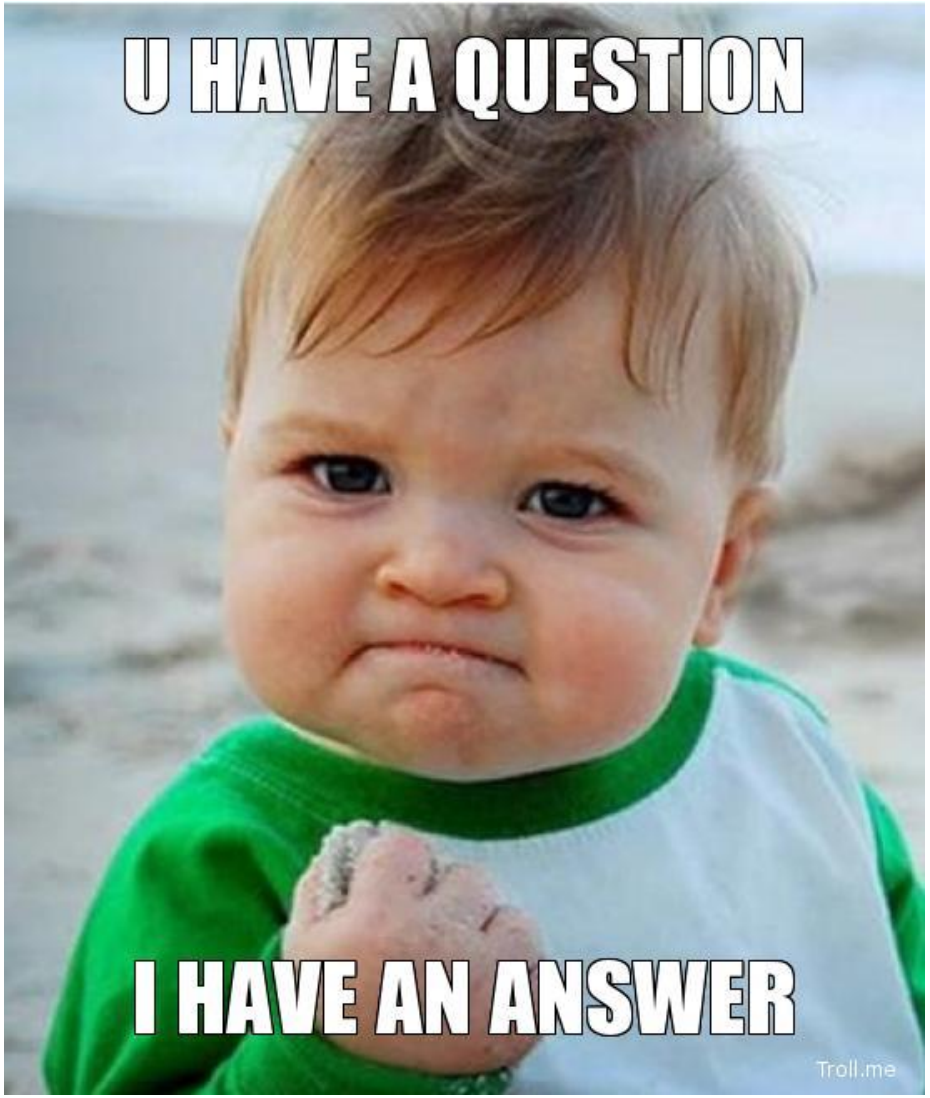
1. Fine Grinding Market
2. Ball Mill : 25 mm versus Small Media
3. Ball Mill versus Isamill
4. Ball Mill versus Vertical Stirred Mill
5. Industrial Scale-Up

TESTING INTERACTION

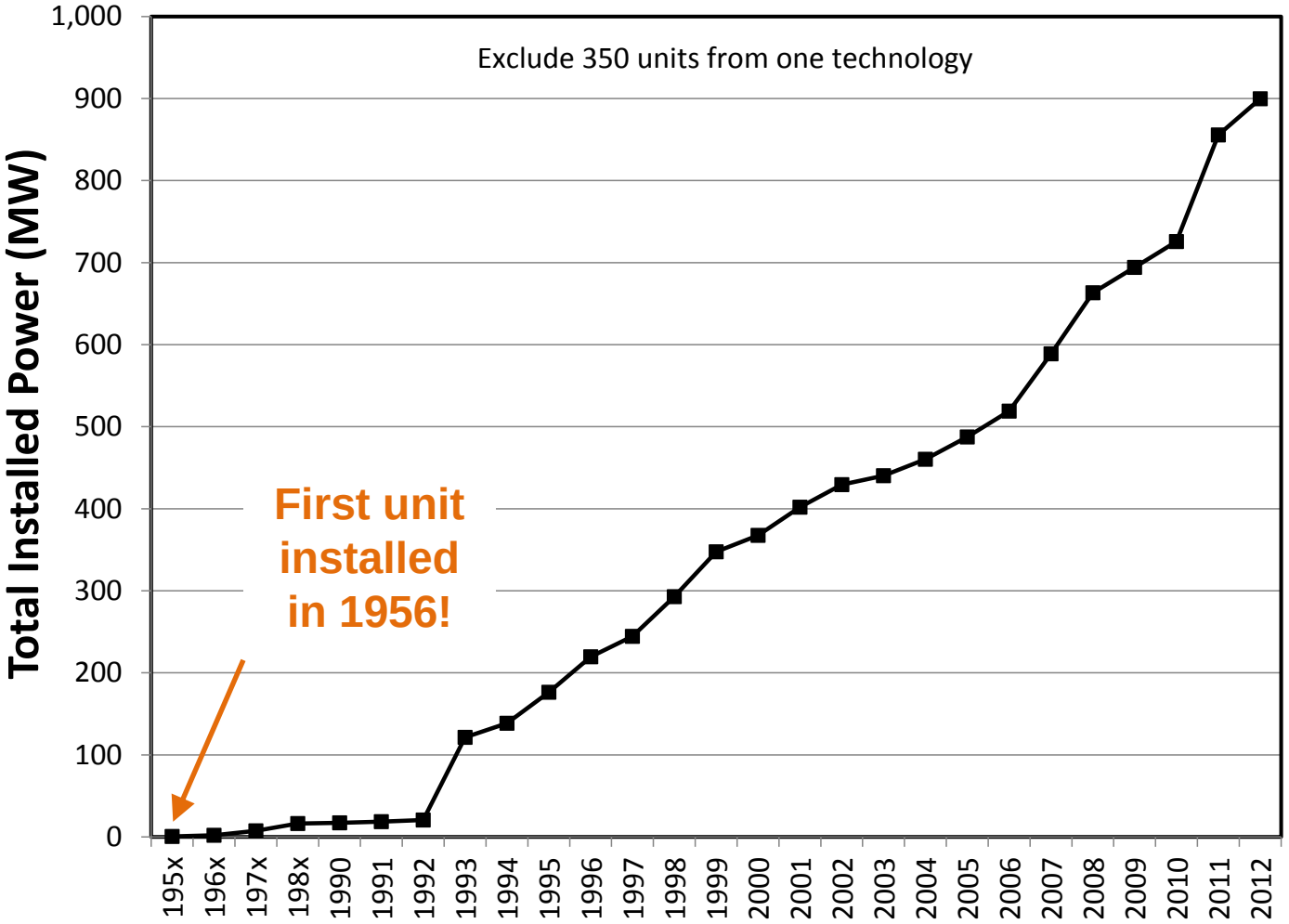
Who hates being asked questions by speakers?



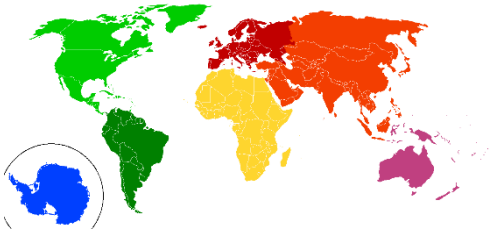
TESTING INTERACTION



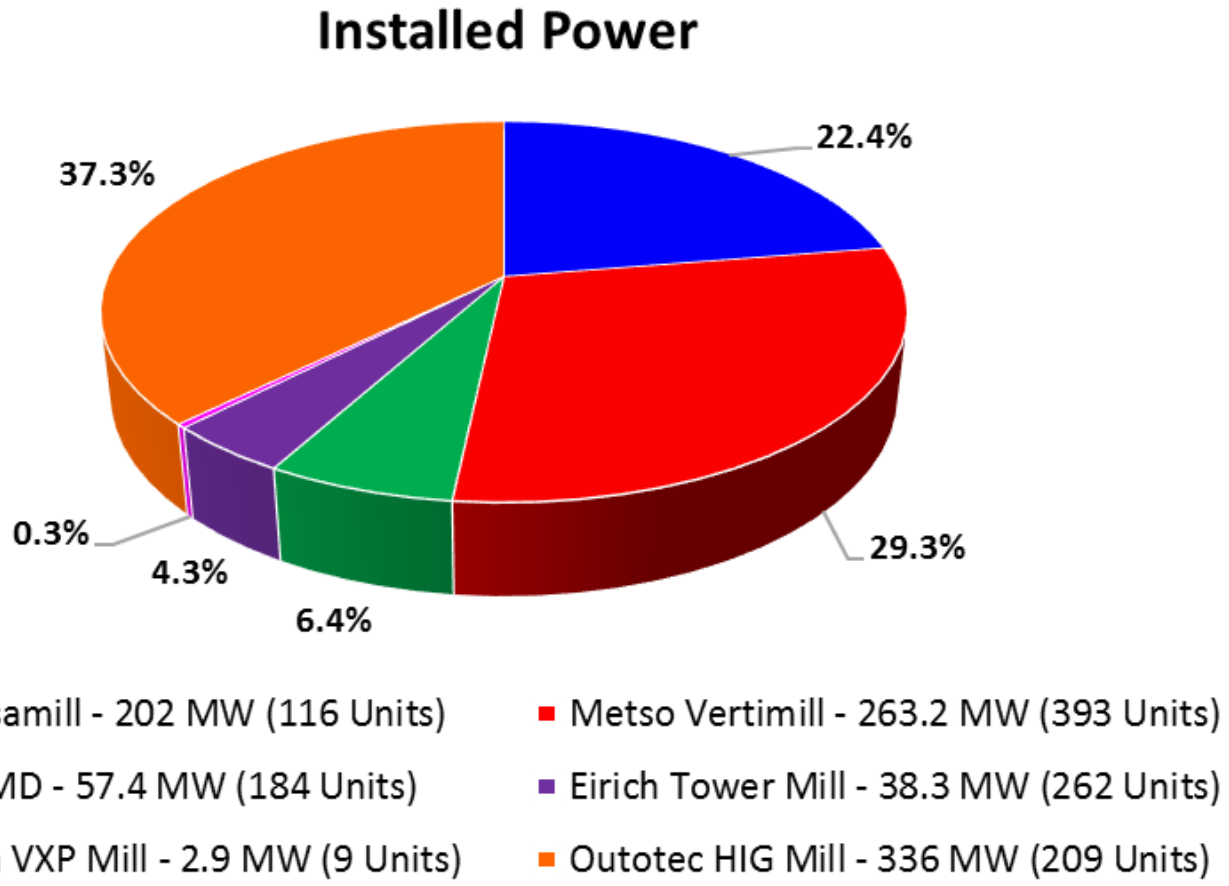
Fine Grinding Growth Trend



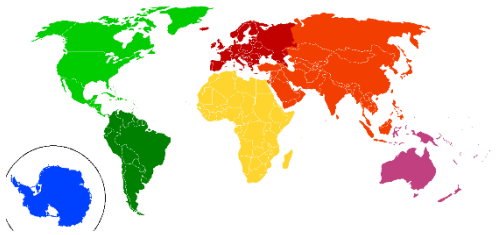
Total of nearly 900 MW installed power – not all listed



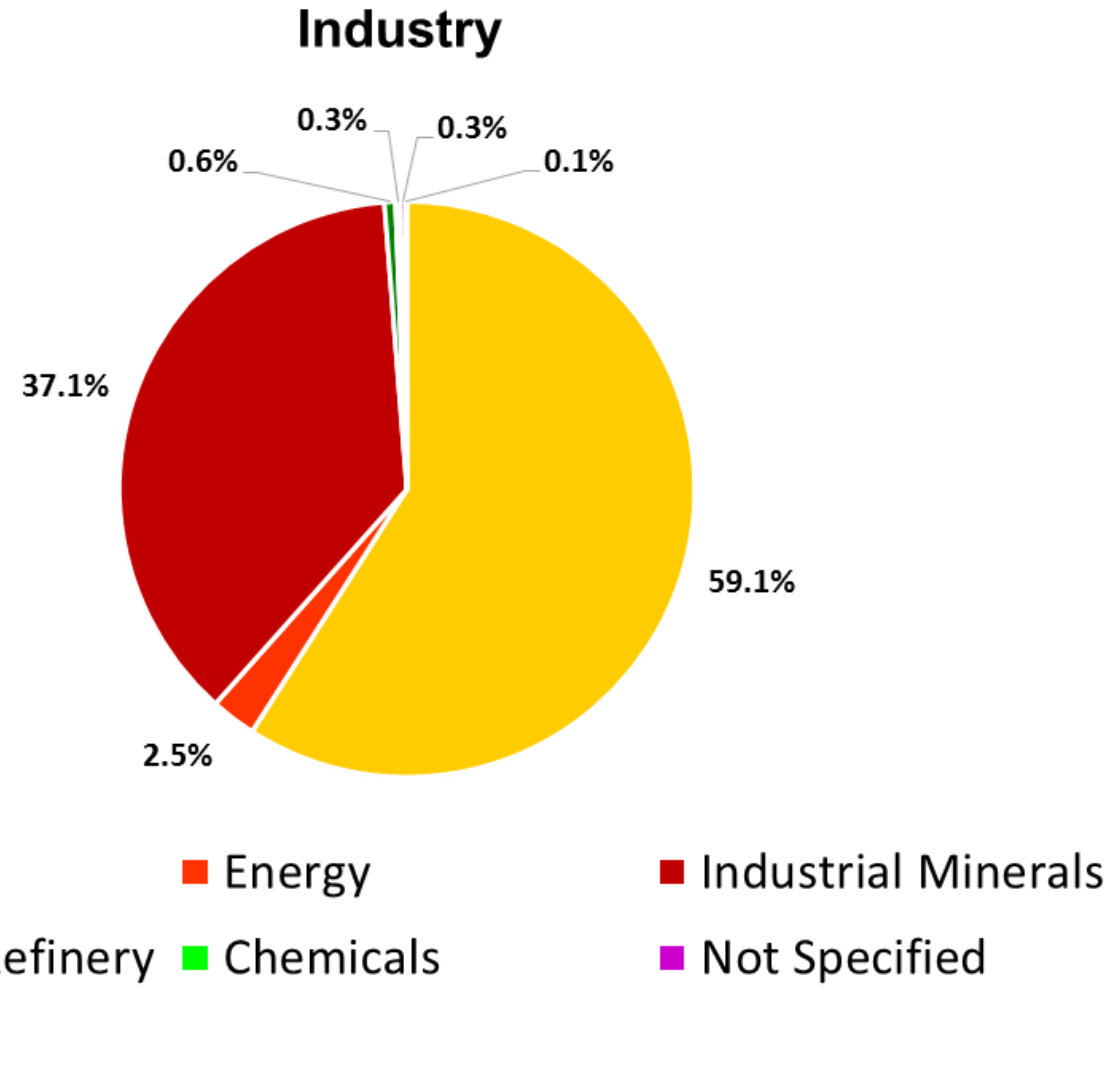
Fine Grinding Technologies

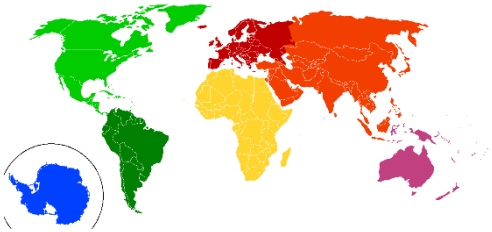


- 350 SMD units missing from former manufacturer…
- … over 1523 units installed world wide.

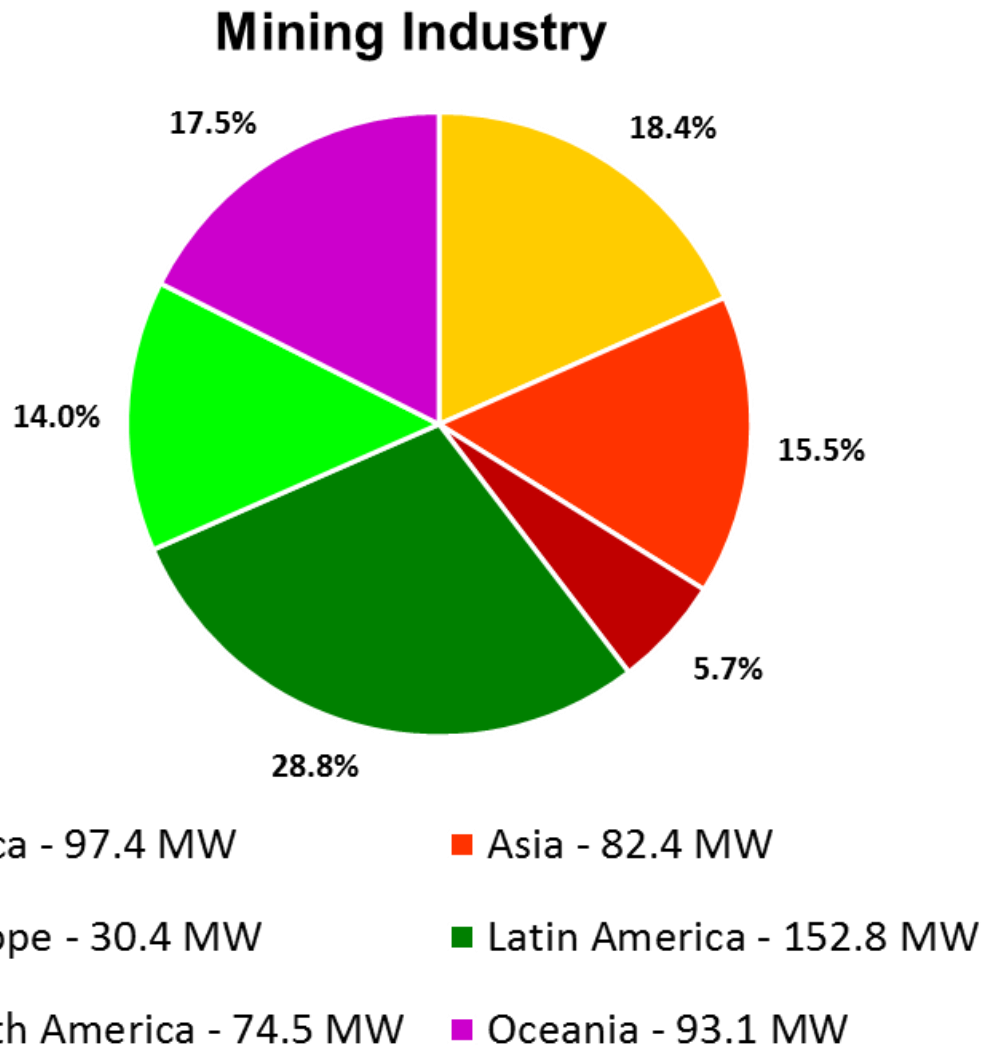


Fine Grinding Technologies





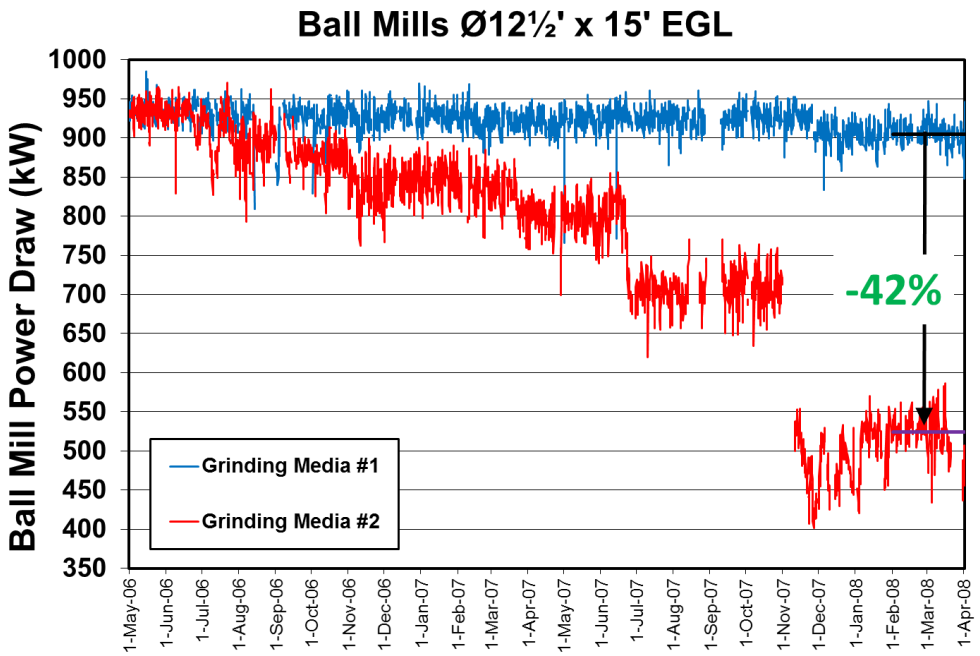
Fine Grinding Technologies



Ball Mill : 25 mm versus Small Grinding Media

$$Power\ Reduction\ (kW)$$

$$Wear\ Rate\ \left(\frac{gr}{kWh}\right)$$



Grinding Media #1

36.8 gr/kWh

Grinding Media #2

62.0 gr/kWh

Ball Mill : 25 mm versus Small Grinding Media

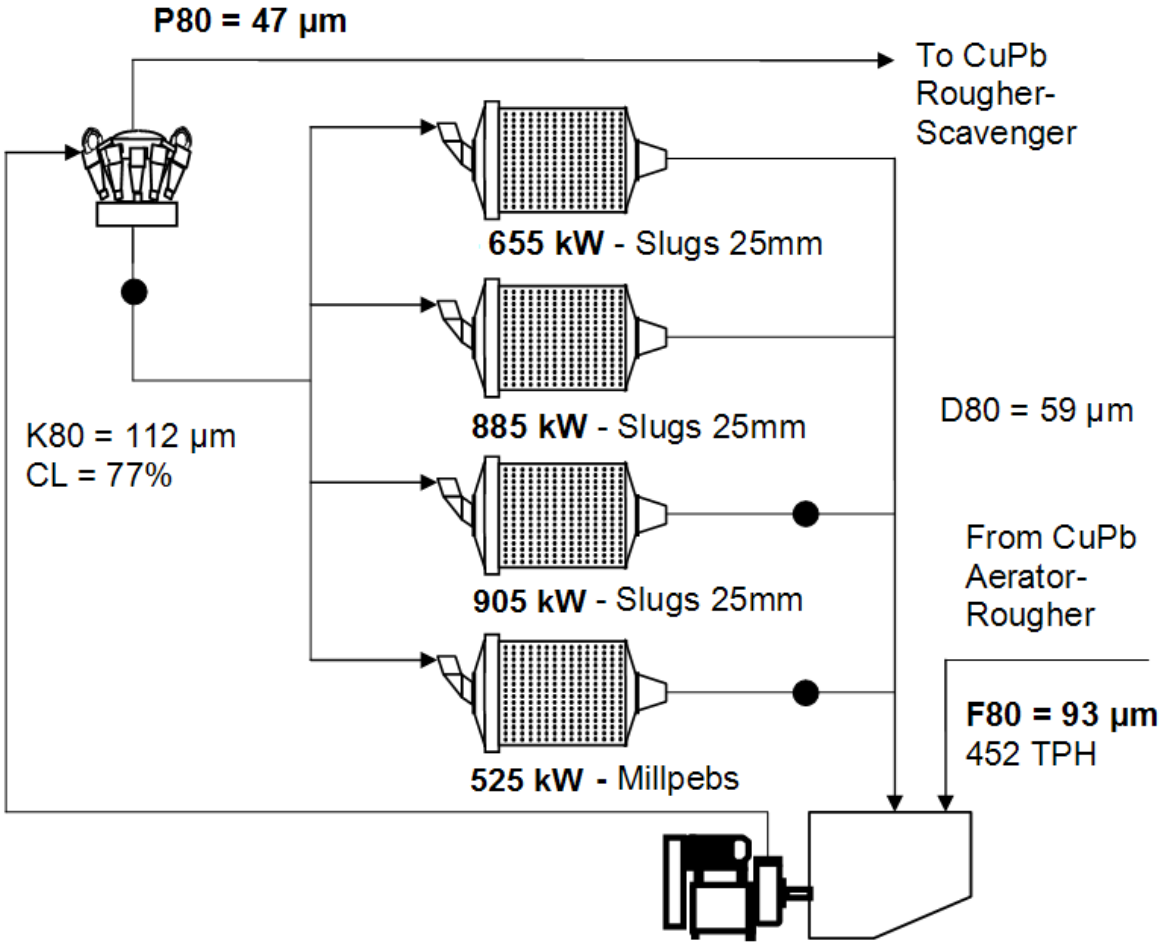
What is the more important?

$$\boldsymbol{Power\ Reduction\ (kW)?}$$

$$\boldsymbol{Wear\ Rate\ \left(\frac{gr}{kWh}\right)?}$$

Ball Mill : 25 mm versus Small Grinding Media

Brunswick Mine (1964-2013)



Ball Mill : 25 mm versus Small Grinding Media

Brunswick Mine (1964-2013)

3 Months Performance		Secondary Ball Mill	
Media	Unit	25mm	Millpebs
Running Hours	h	1 737.8	1 737.8
Underflow K80	µm	102	102
Discharge D80	µm	72	73
Power	kW	**905**	**525**
Tonnage	TPH	113	113
Energy	kWh/t	8,01	4,65
Total Added Media	kg	**173 600**	**169 290**
Average	t/month	**57.9**	**56.4**

Power was reduced by 42%

How many of you think the consumption is different?

Ball Mill : 25 mm versus Small Grinding Media

Wear Rate for Unknown TPH (gr/kWh)

$$WR = \frac{Total\ Added\ Media\ (gr)}{Total\ Hours\ (h)} \times \frac{1}{Power\ (kW)}$$

25 mm Media

$$WR_{25mm} = \frac{173\,600\ kg \times 1000}{1\,737.8\ h} \times \frac{1}{905\ kW} = \frac{33.8 \frac{gr}{h}}{905\ kW} = 36.8 \frac{gr}{kWh}$$

Small Media (5-12mm)

$$WR_{25mm} = \frac{169\,290\ kg \times 1000}{1\,737.8\ h} \times \frac{1}{525\ kW} = \frac{32.5 \frac{gr}{h}}{525\ kW} = 62.0 \frac{gr}{kWh}$$

Ball Mill : 25 mm versus Small Grinding Media

« There is no such thing as a technical optimum. The Optimum is always defined by economics. »

McIvor (1989), Metcom GPD – Module 1

Ball Mill : 25 mm versus Small Grinding Media

Annual Cost with 92% Availability

Media	Unit	25mm	Millpebs
Power Draw	kW	3,350	2,010
Running Hours	h/year	8,059	8,059
Energy Consumption	MWh/year	27,000	16,200
Grinding Media Consumption	t/year	2,735	2,735
Energy Pricing	CAD/kWh	**0.045**	**0.045**
Grinding Media Pricing	CAD/t	**1,000**	**1,250**
Energy Cost	kCAD/year	**2,736**	**3,078**
Grinding Media Cost	kCAD/year	**1,215**	**729**
Total Cost	kCAD/year	**3,951**	**3,807**

Annual Savings of nearly 143,000 CAD/year

Ball Mill : 25 mm versus Small Grinding Media

Annual Cost with 92% Availability

Media	Unit	25mm	Millpebs
Power Draw	kW	3,350	2,010
Running Hours	h/year	8,059	8,059
Energy Consumption	MWh/year	27,000	16,200
Grinding Media Consumption	t/year	2,735	2,735
Energy Pricing	CAD/kWh	**0.200**	**0.200**
Grinding Media Pricing	CAD/t	**1,000**	**1,250**
Energy Cost	kCAD/year	**2,736**	**3,078**
Grinding Media Cost	kCAD/year	**5,400**	**3,240**
Total Cost	kCAD/year	**8,136**	**6,318**

Annual Savings of more than 1,800,000 CAD/year

Ball Mill versus Vertical Stirred Mill

What is the most energy efficient technology?

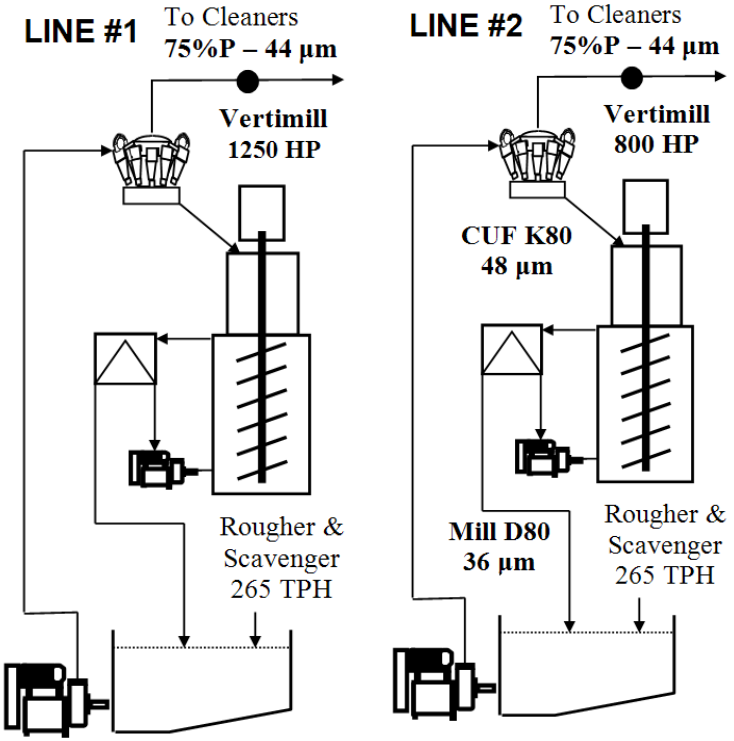
Conventional Ball Milling

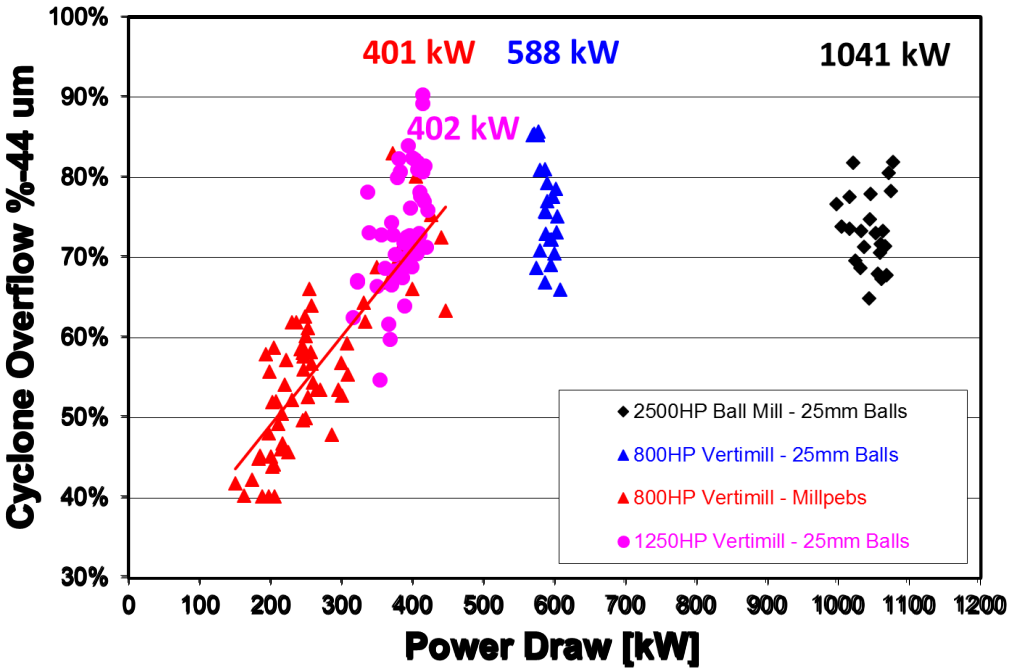
Ball Mill?

Vertical Stirred Mill?

Vertimill

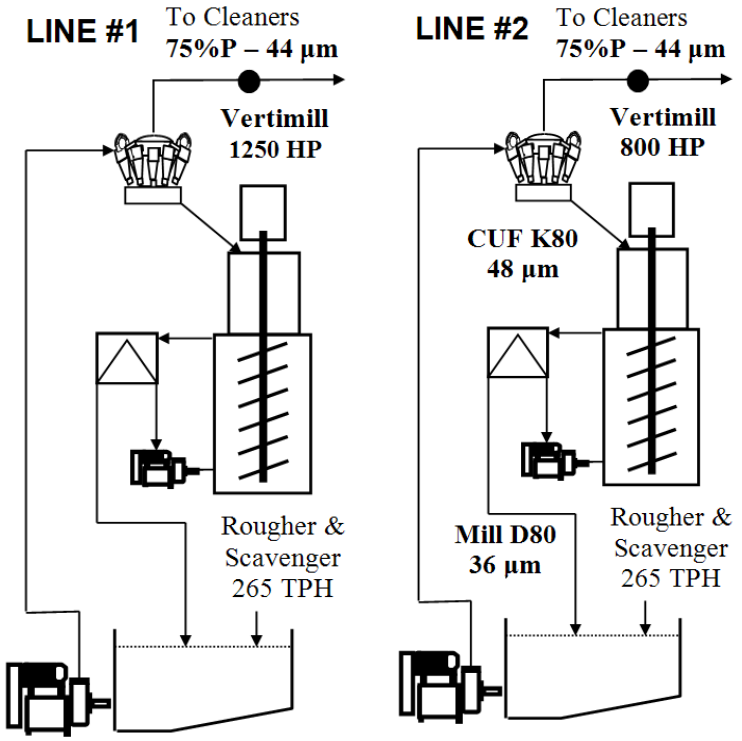
Ball Mill versus Vertical Stirred Mill

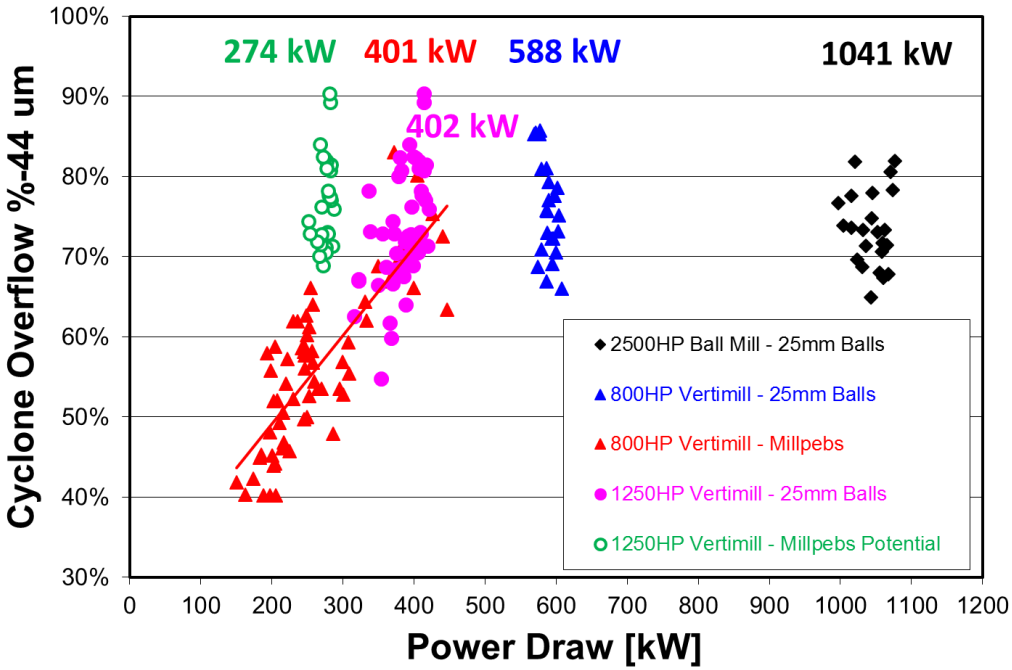




- A vertical mill was drawing 43% less power than a ball mill
- Small media was 30% more efficient than 25mm balls in VSM
- The new Vertimill with 25mm media was 60% more efficient than the ball mill

Ball Mill versus Vertical Stirred Mill





Potential power reduction of vertical stirred mill with small media is 72% in compared to ball mill with 25 mm balls

Ball Mill versus Vertical Stirred Mill

Media	Unit	Ball Mill 25mm	Vertimill 25mm	Vertimill Millpebs
Power Draw	kW	3,350	2,010	940
Running Hours	h/year	8,059	8,059	8,059
Energy Consumption	MWh/year	27,000	16,200	7,576
Media Consumption	t/year	2,735	2,735	2,735
Energy Pricing	CAD/kWh	**0.200**	**0.200**	**0.200**
Grinding Media Pricing	CAD/t	**1,000**	**1,250**	**1,250**
Energy Cost	kCAD/year	**2,736**	**2,736**	**3,078**
Grinding Media Cost	kCAD/year	**5,400**	**3,240**	**1,515**
Total Cost	kCAD/year	**8,136**	**5,976**	**4,593**

Actual annual savings is 2.16 M CAD/year

Additional savings of 1.38 M or total of 3.5 M CAD/year

Ball Mill versus Isamill

What is the most energy efficient technology?

Conventional Ball Milling

Isamilling

Ball Mill?

Isamilling?

Ball Mill versus Isamill

Kumtor Mine (Kyrgyz Republic)

Regrind Ball Mill Ø16½' x 35' EGL

Mill	Media	kW	TPH	kWh/t	F80 µm	P80 µm	Overflow %-20 µm	WOI
ISA	2½-3½mm	1885	80,0	23,4	135	62	N/A	
RGD Before	25mm	3717	88,2	42,1	129	19	88,0%	
RGD Trial	25%Mpbs	3333	135,0	24,7	130	<19	90,1%	
RGD After	25mm	3895	119,0	32,7	-	-	87,8%	

- Pease et al. (2006). *Autogenous and Inert Milling using the Isamill*, SAG 2006 Conference Proceedings, Ed: Allan, Major, Flintoff, Klein & Mular, Vol. II, pp. 231-245.
- ISA mill shows some potential for regrind application…
- …but small media in a ball mill shows the same potential (Δ=5.5%)

Ball Mill versus Isamill

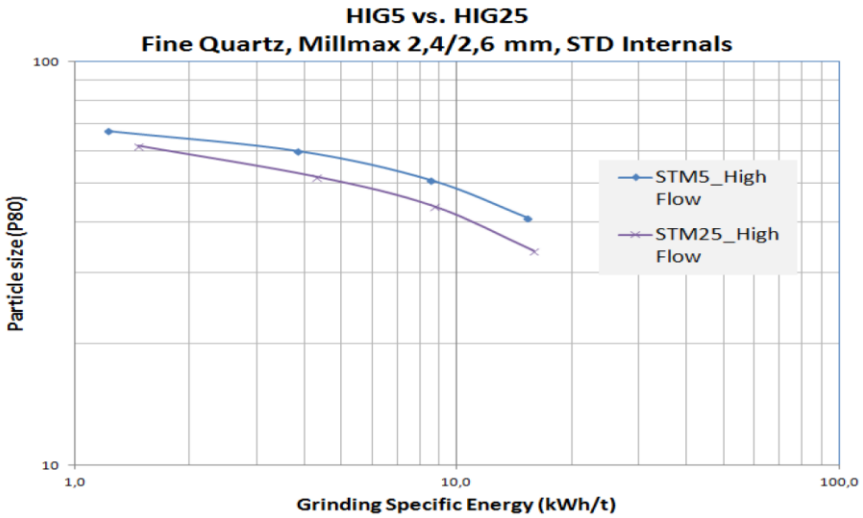
Kumtor Mine (Kyrgyz Republic)

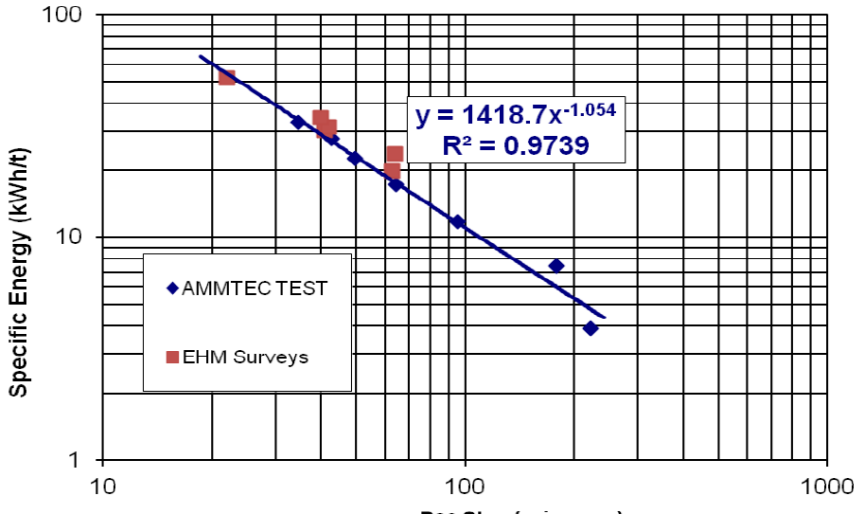
Regrind Ball Mill Ø16½' x 35' EGL

Mill	Media	kW	TPH	kWh/t	F80 µm	P80 µm	Overflow %-20 µm	WOI
ISA	2½-3½mm	1885	80,0	23,4	135	62	N/A	57,6
RGD Before	25mm	3717	88,2	42,1	129	19	88,0%	29.8
RGD Trial	25%Mpbs	3333	135,0	24,7	130	<19	90,1%	16,7
RGD After	25mm	3895	119,0	32,7	-	-	87,8%	-

- Based on WOI, small media in a ball mill gives better energy efficiency than the ISA Mill
- **Regardless, fine grinding equipment can be as inefficient as a ball mill if not operated properly.**
- **All your annual savings are gone!**

Industrial Scale-Up





Roitto, I., Lehto, H., Paz, A. & Astholm, M. (2013). *Stirred Milling Technology – A New Concept in Fine Grinding,* AusIMM MetPlant 2013, Perth, Australia, pp.190-201.

Larson, M., Anderson G., Barns, K., Villadolid, V. (2013). *IsaMill 1:1 Direct Scaleup from Ultrafine to Coarse Grinding,* MEI Comminution 2012, April 19th 2012, Cape Town, South Africa.

1. Work in progress by all manufacturers.
2. What about the operating conditions & efficiency?

Grinding testwork measures the kWh/t required to get P80

Mill Power Draw Calculation

Power equations are used to size mills

Nordberg Brochure circa 1970

Power draw (HP) = A*B*C*D

A = Diameter factor = 0.1765 x $ID^{2.5}$ (ft.)

B = Load factor (SAG = 4, BM = 5 - dependent on charge, SG, and weight)

C = Speed factor = 0.1838 for 75% critical

D = EGL in feet

Industrial Scale-Up

Power equations with Small Grinding Media

Media & Filling Degree Measured	DCS	Morrell	Allis-Chalmer	Nordberg
25mm Slugs @ 33.0%	910 kW	1,007 kW	916 kW	880 kW
Millpebs @ 26.8%	**575 kW**	872 kW	785 kW	786 kW

1. Calculated power of ball mill do not match with industrial measurement when using small media
2. Power equation exists for vertical stirred mill (JKTech Mineral Comminution Circuits)

Conclusion

1. 6 fine grinding technologies are available from 5 manufacturers with over 1523 units representing 900 MW installed worldwide.
2. Ball mill power can be reduced significantly in fine grinding reducing the OPEX in remote area.
3. Fine grinding technology can reduce the OPEX further, CAPEX to be compared.
4. However, if not used properly, the FG performance can be inefficient, losing the OPEX savings.
5. Improvement continues for industrial scale-up but power models need to be developed for design purposes.

Further Development

1. Starkey & Associates is looking to have all those new fine grinding technologies in pilot station in Quebec.
2. We will have both steel and ceramic grinding media available for testing.
3. First step is to reproduce the industrial scale in pilot station to determine best operating conditions and develop power equations.
4. Second step is to develop a fine grinding test for laboratory bench scale.

Acknowledgements

All manufacturers to have provided the installation list of their fine grinding equipment.

Thank you!
Questions?