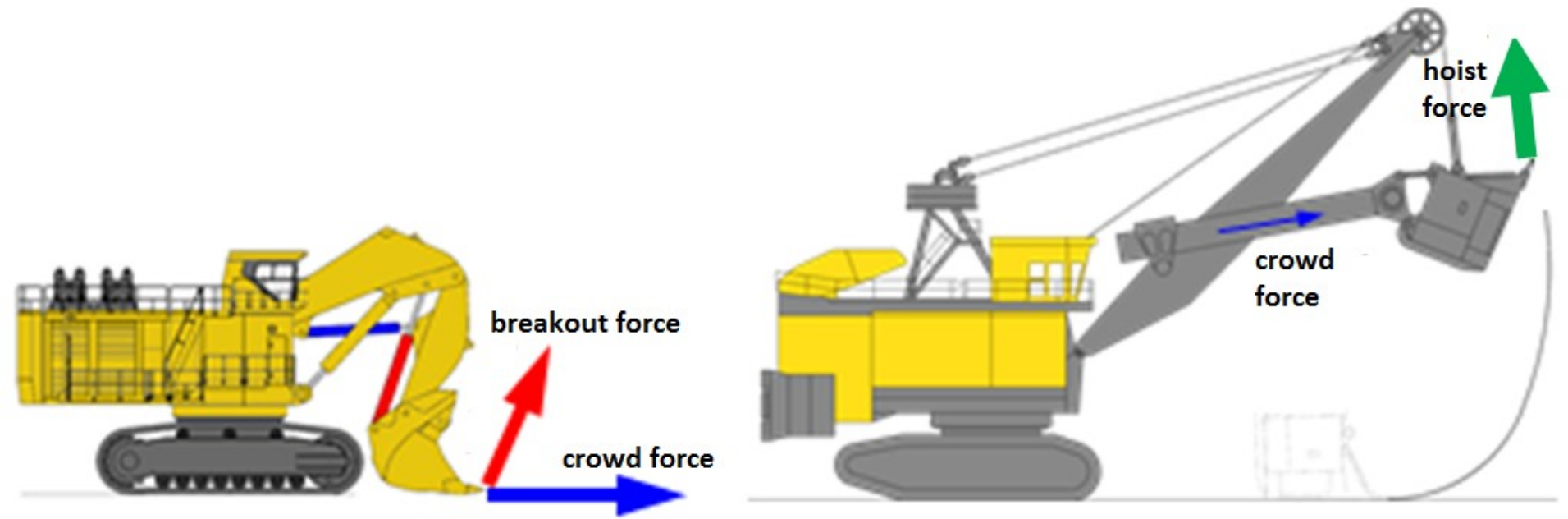


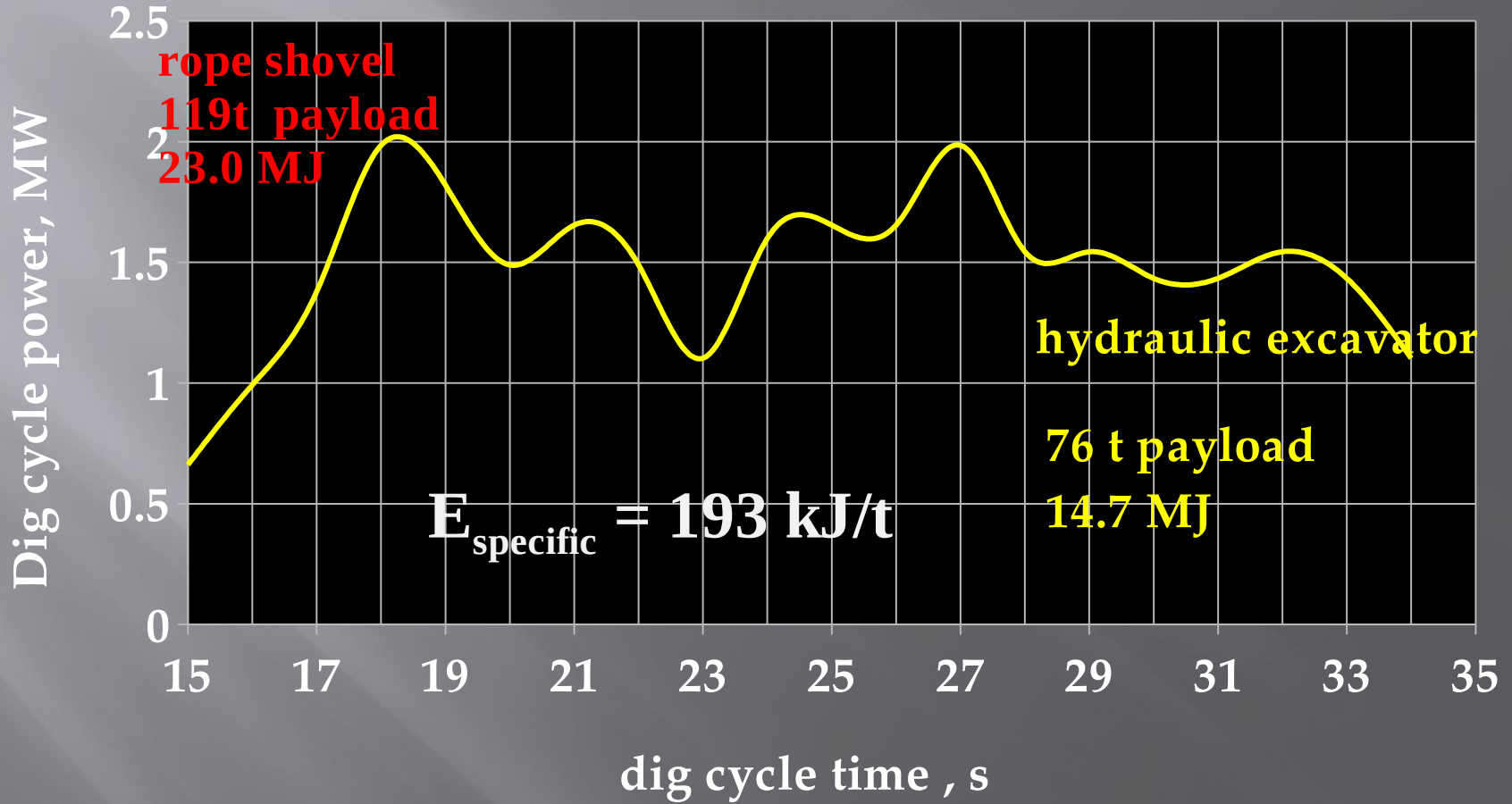
# HYDRAULIC EXCAVATOR VS. ROPE SHOVEL PERFORMANCE

Rodion Andreev, Tim Joseph  
John Sammut, Mark Curley  
University of Alberta, Canada

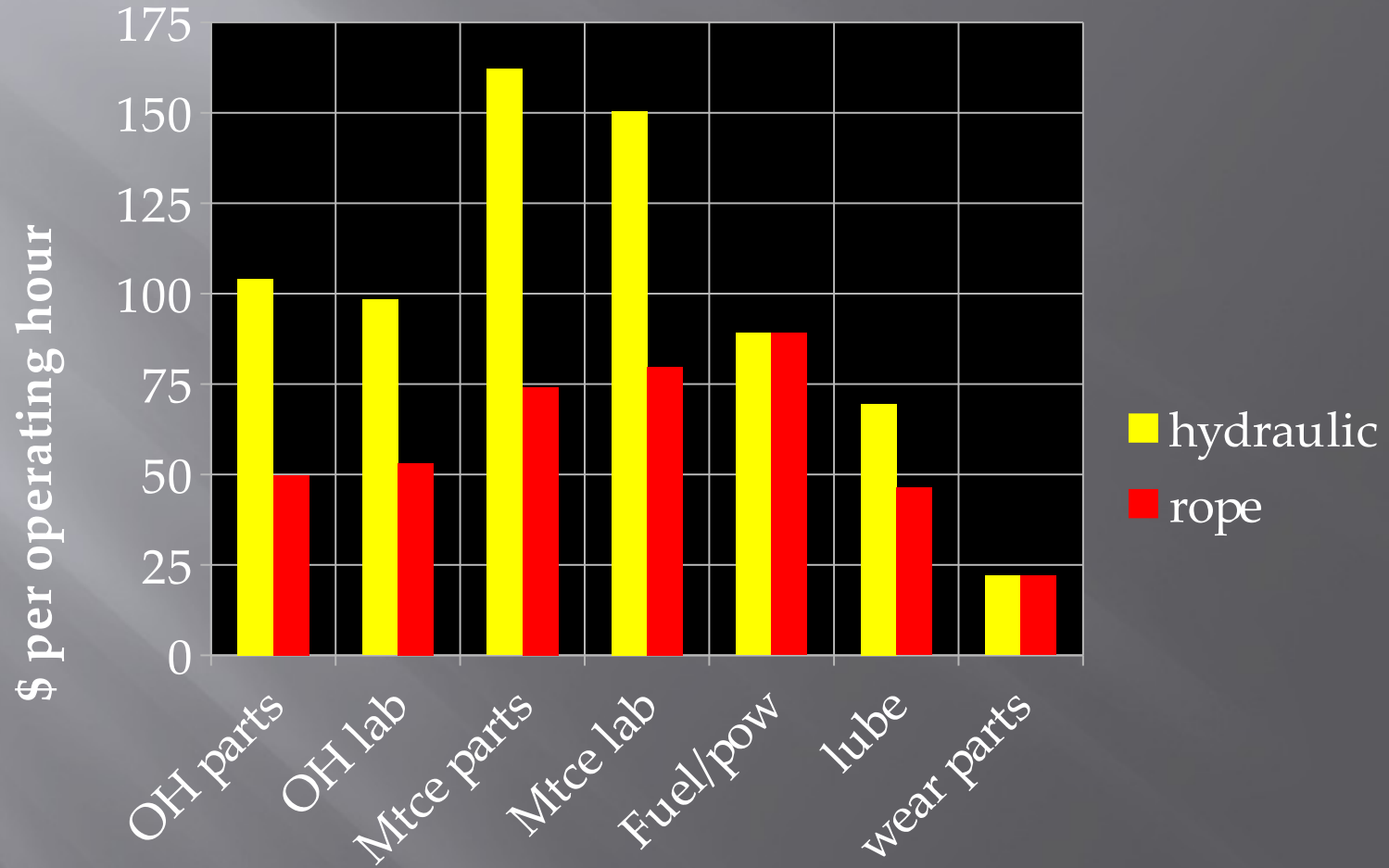
Recall Tim & John at H&L 2013  
Ultra class excavator vs. shovel  
> 40 m<sup>3</sup> capacity



# Specific energy comparison

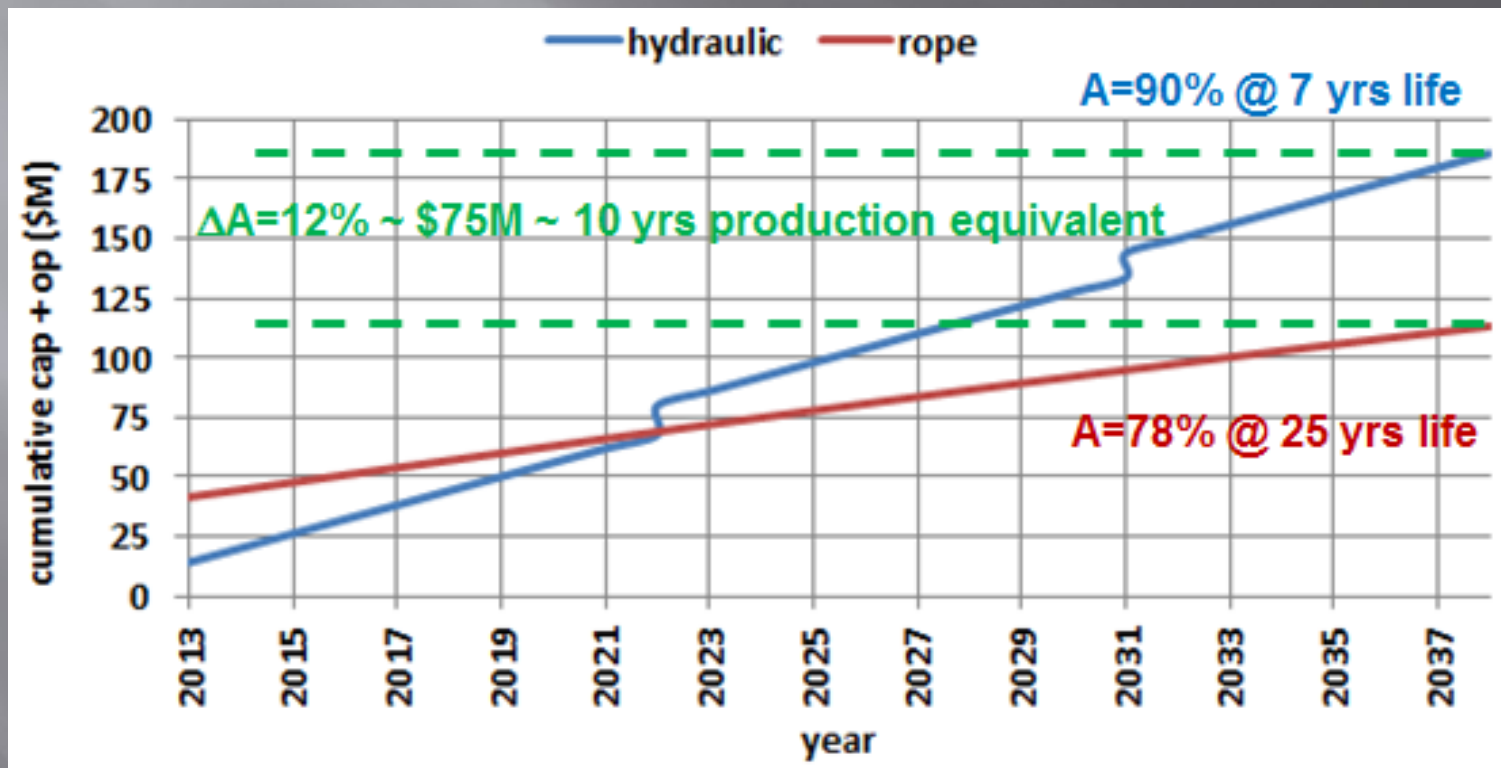


# Operating & maintenance cost



# Cumulative cost of ownership

## Sammut & Joseph, 2013 H&L



# Availability

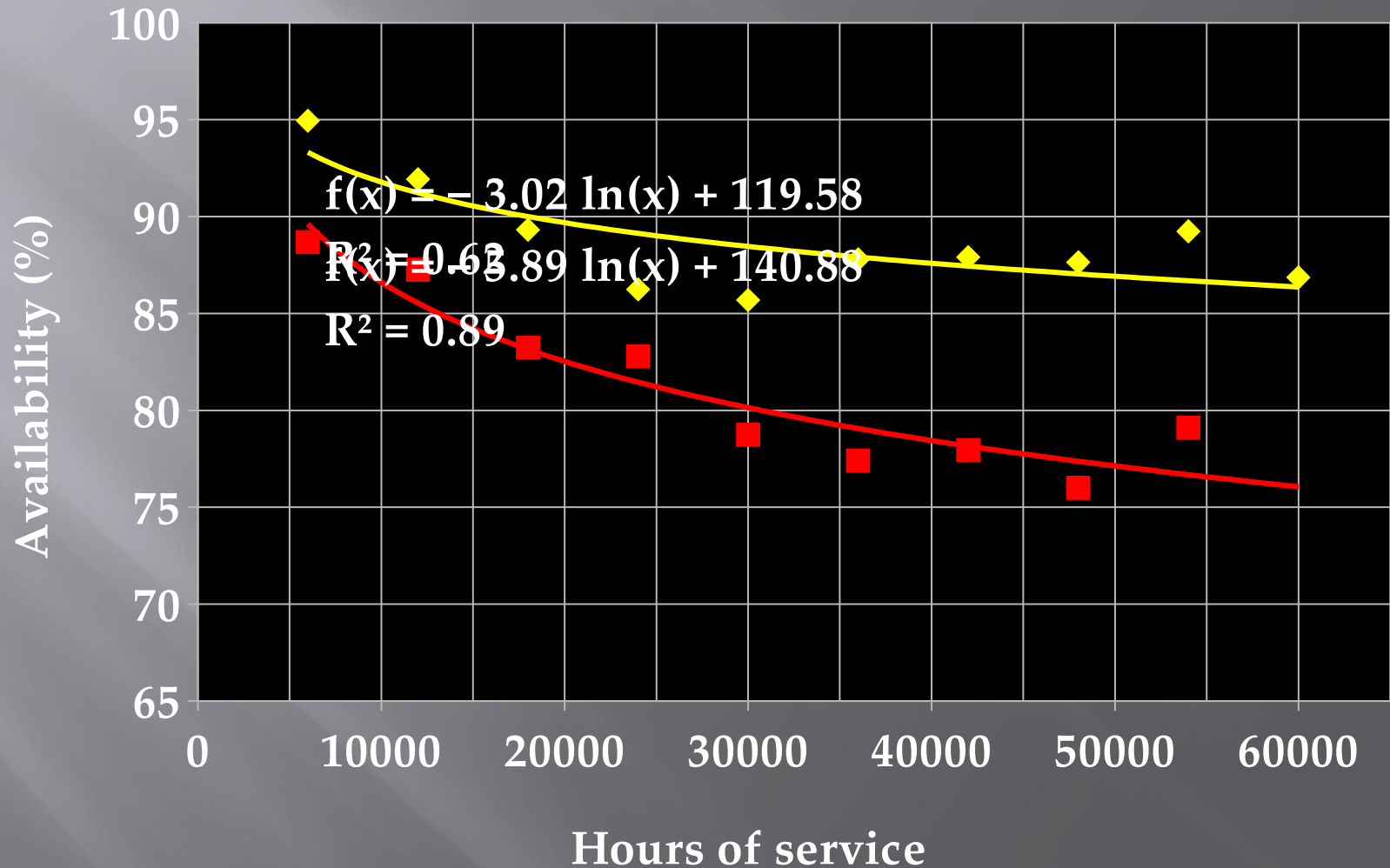
$$A = \left\{ \frac{\text{Available hours}}{\text{Scheduled hours}} = \frac{\text{Available hours}}{(\text{Calendar hours} - \text{Scheduled delays})} \right. \\ \left. = \frac{(\text{Scheduled hours} - \text{Maintenance delays})}{(\text{Calendar hours} - \text{Scheduled delays})} \right\} \times 100\%$$

%

# Operations' Availability data

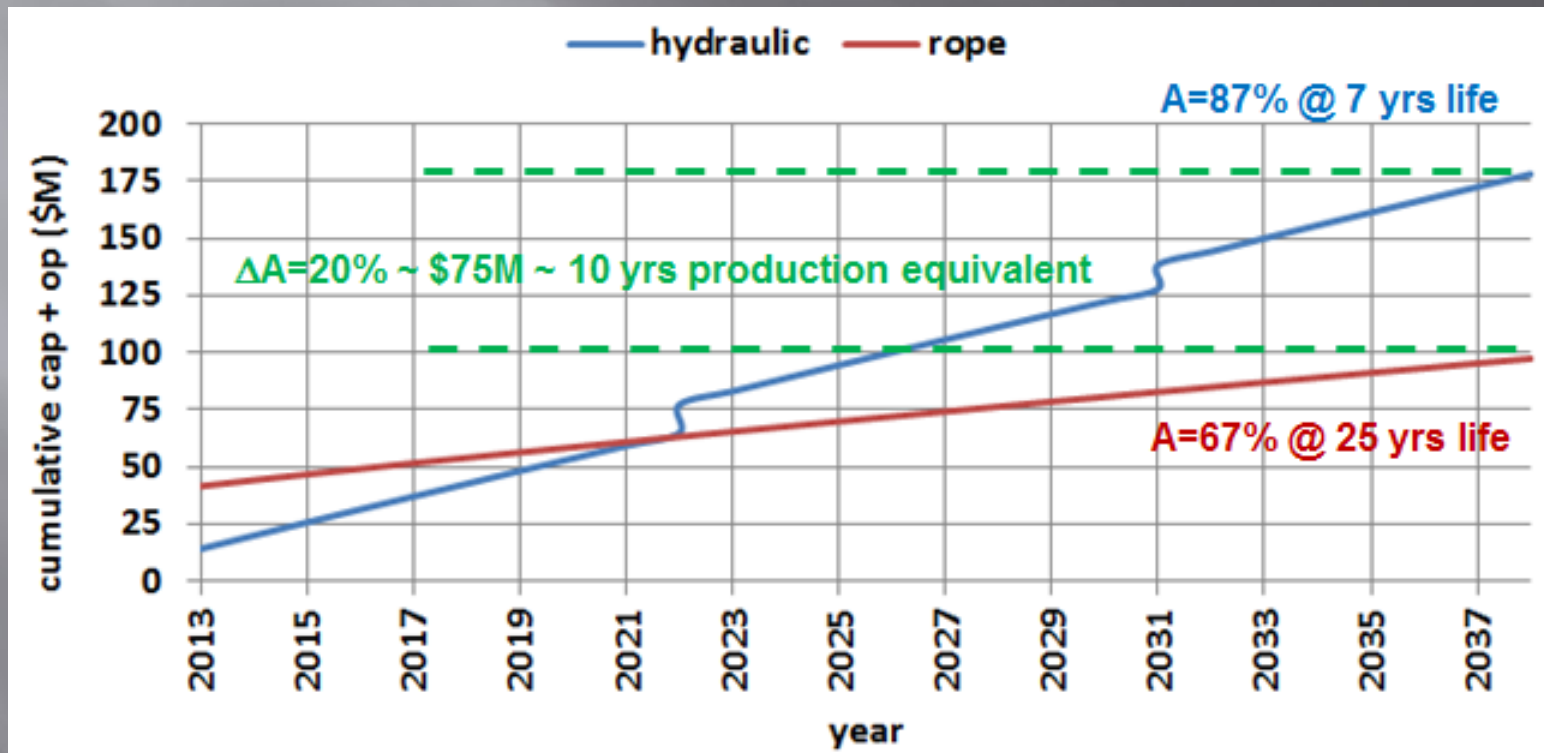
m3 cap	Mined ore	Region	#	6000	12000	18000	24000	Op.hrs					
								30000	36000	42000	48000	54000	60000
10	Coal	Europe	4	94.5	89.7	88.5	87.6						
11	Coal	Europe	4	92.2	91.7	86.9	77.3	82.6	82.5	80.3	76.1		
15	Coal	Asia	8	97.3	96.2	95.1	92.6	92.8	88.1				
22	Coal	Lat Am	5	94.3	89.6	88.8	89.0	90.2	90.8	91.0	93.2		
22	Coal	Europe	1	95.7	91.6	81.5	73.7	66.1	86.7				
22	Coal	Asia	14	94.5	91.4	91.0	89.4	87.8	86.4	90.6			
22	Coal	Africa	5	95.6	94.4	94.0	89.2						
19	Iron Ore	Australia	5	81.2	78.6								
19	Iron Ore	Africa	5	75.0	84.8	91.6							
19	Copper	Lat Am	1	90.9	81.0	87.2							
28	Coal	Europe	1	94.5	92.7	78.0	76.1						
28	Coal	Australia	1		93.4								
28	Coal	US	2	95.8	93.4	90.4	94.9		88.9	90.8	91.0	92.6	
25	Iron Ore	Australia	5	79.6	77.4	81.5		76.8	77.9				
25	Iron Ore	Africa	2		81.6	77.6							
25	Iron Ore	Europe	2	91.3	89.2	84.1	83.1	88.9					
28	Copper	Lat Am	17	88.2	85.8	81.8	82.6	73.8	82.2	82.8	84.6	87.9	85.5
28	Phosphate	Africa	1					95.0	95.0				
25	Uranium	Africa	4						92.4		96.0	93.3	93.3
42	Coal	Lat Am	19	95.0	91.4	91.1	90.9	89.3	89.3	89.7	89.2	88.6	91.0
42	Coal	Africa	2		91.5	89.4	84.7						
42	Copper	Lat Am	8	86.5	83.2	72.6	62.7						
10 -18	Coal	Europe	6	86.6	86.6	83.9	87.3	81.5	80.4	76.6	74.4	78.0	69.2
20	Coal	Europe	2	91.8	88.4	77.9	67.7	65.3	59.3				
33	Coal	Europe	2	91.8	88.1	86.6	84.3	83.9	86.5	82.0	80.8	82.4	

# Availability



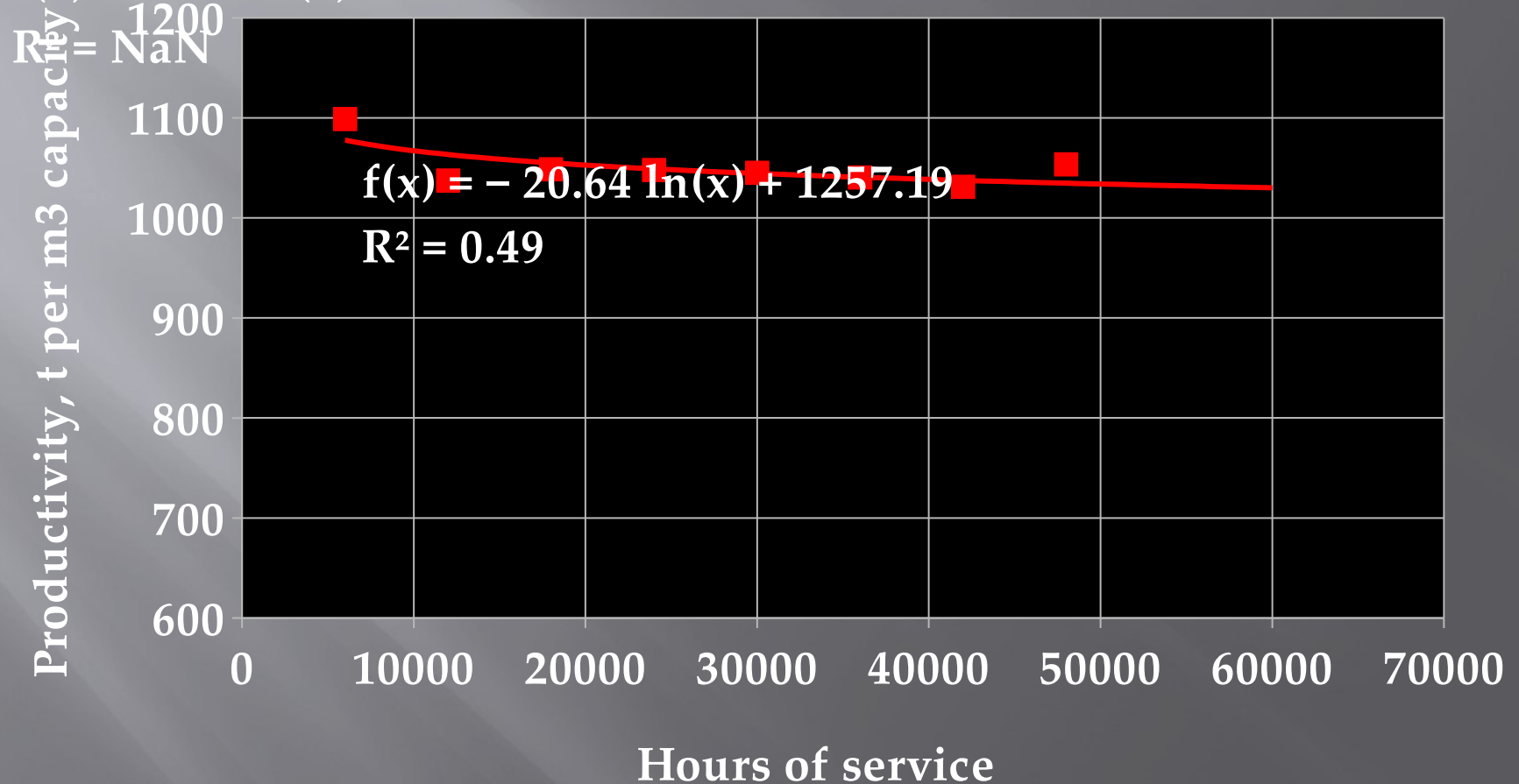


# Joseph & Sammut 2013 modified availability – cost assessment

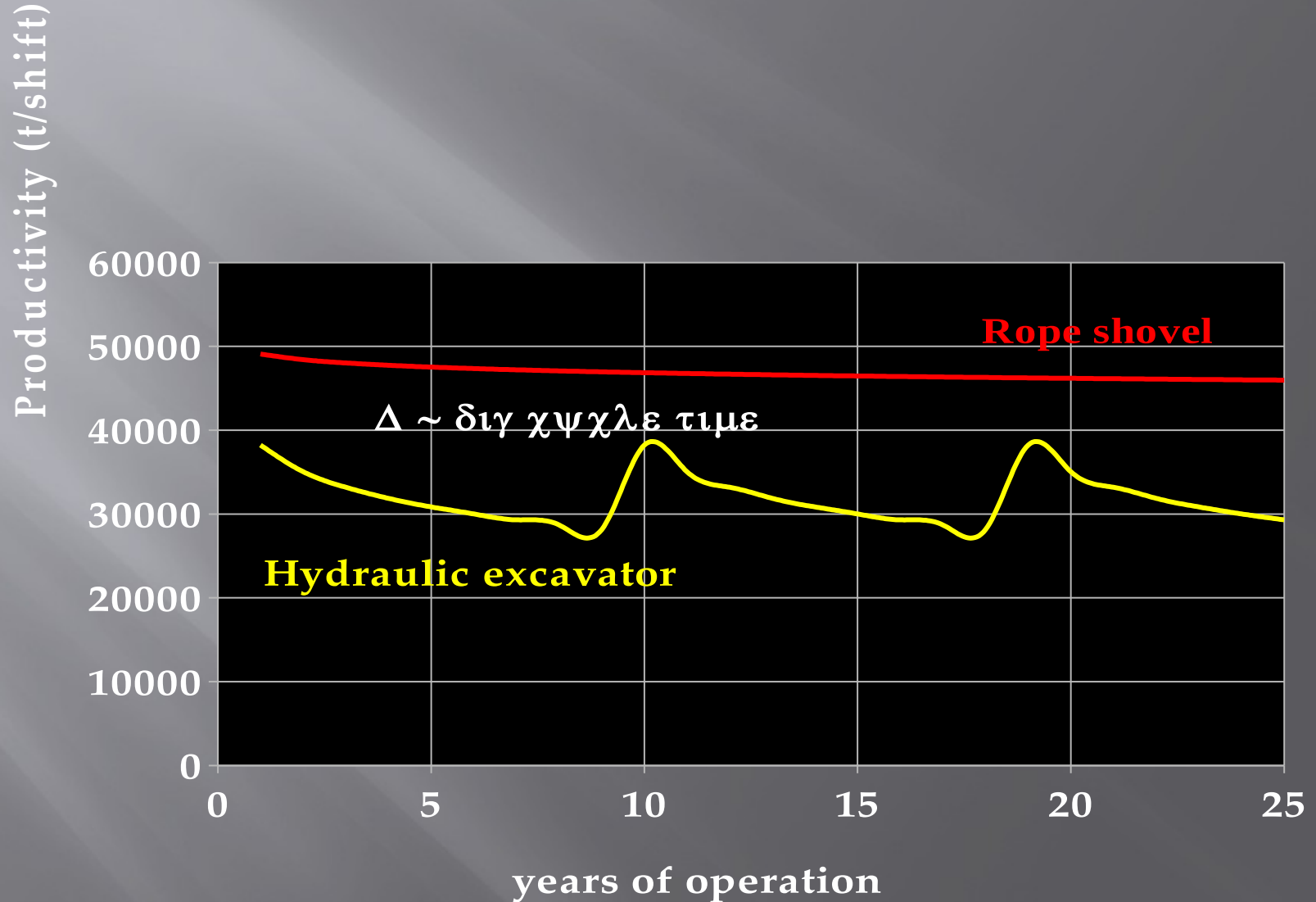


# Productivity per m<sup>3</sup> capacity

$f(x) = \text{NaN} \ln(x) \text{ NaN}$

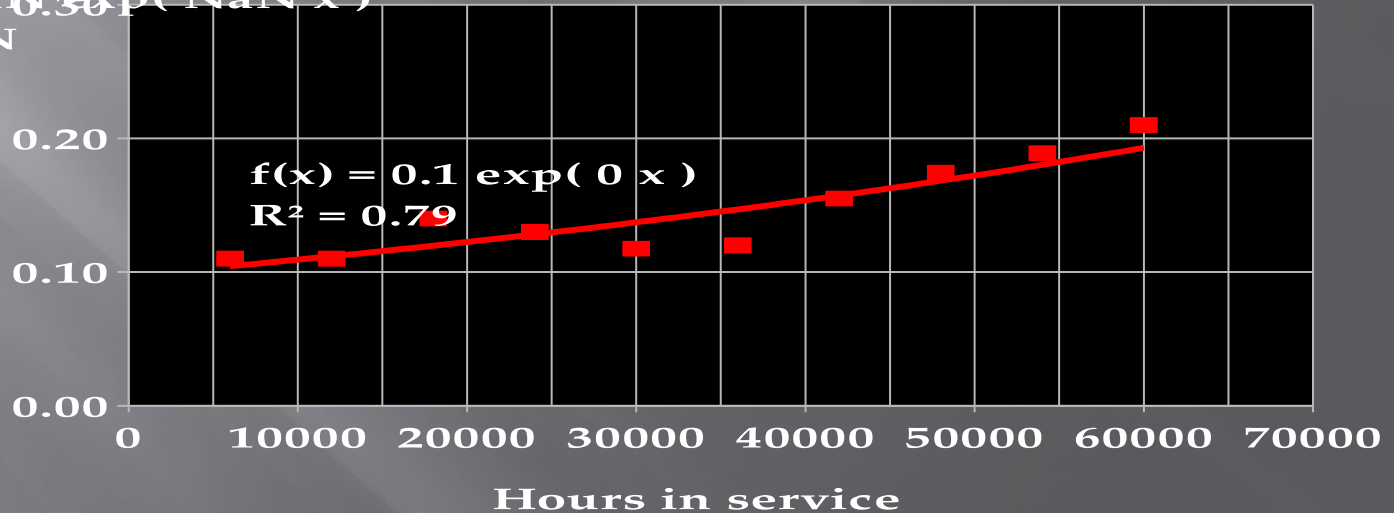


# Productivity over 25 years



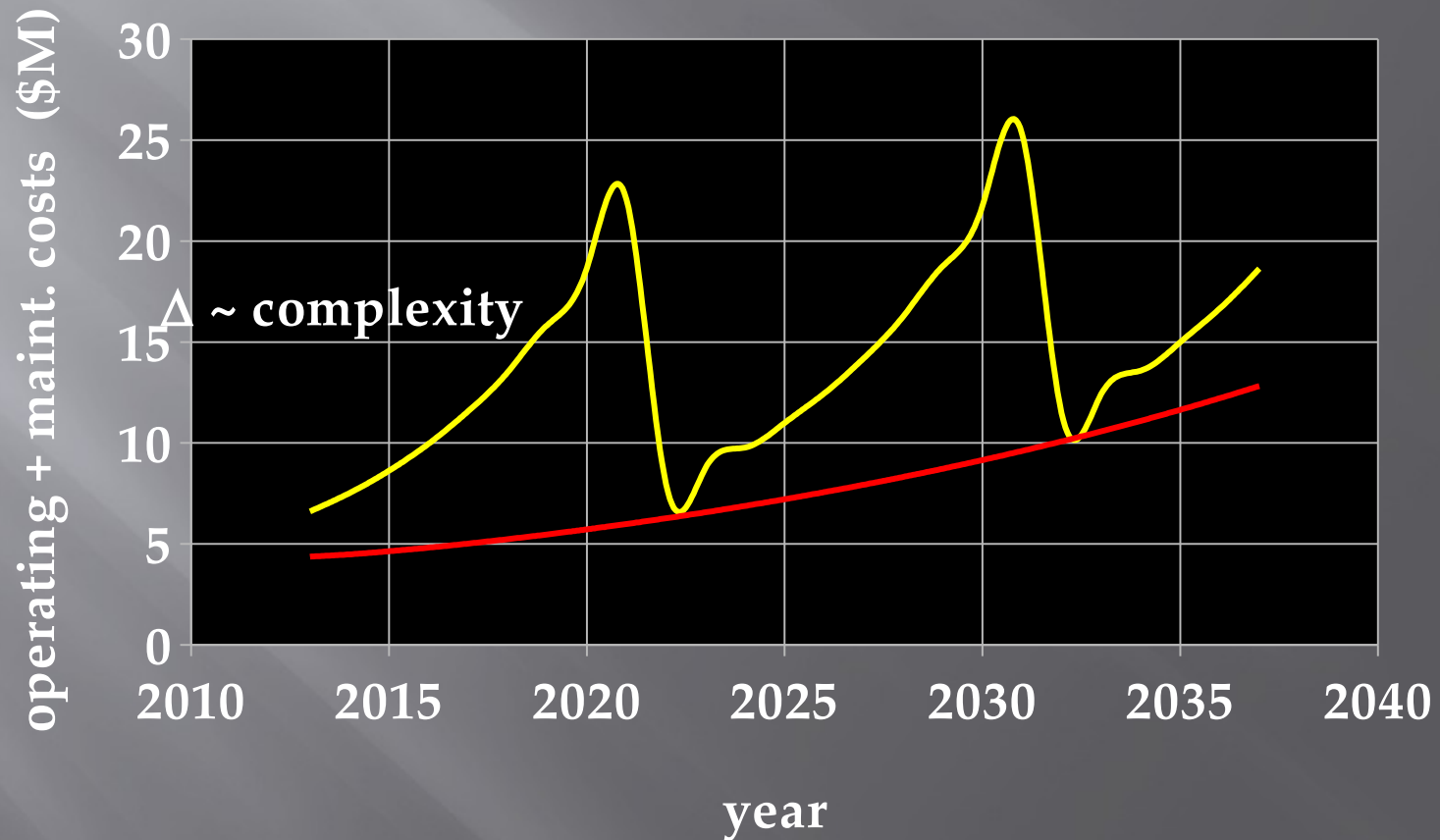
# Maintenace cost per m<sup>3</sup>

$f(x) = \text{NaN} \cdot \exp(\text{NaN} \cdot x)$   
 $R^2 = \text{NaN}$

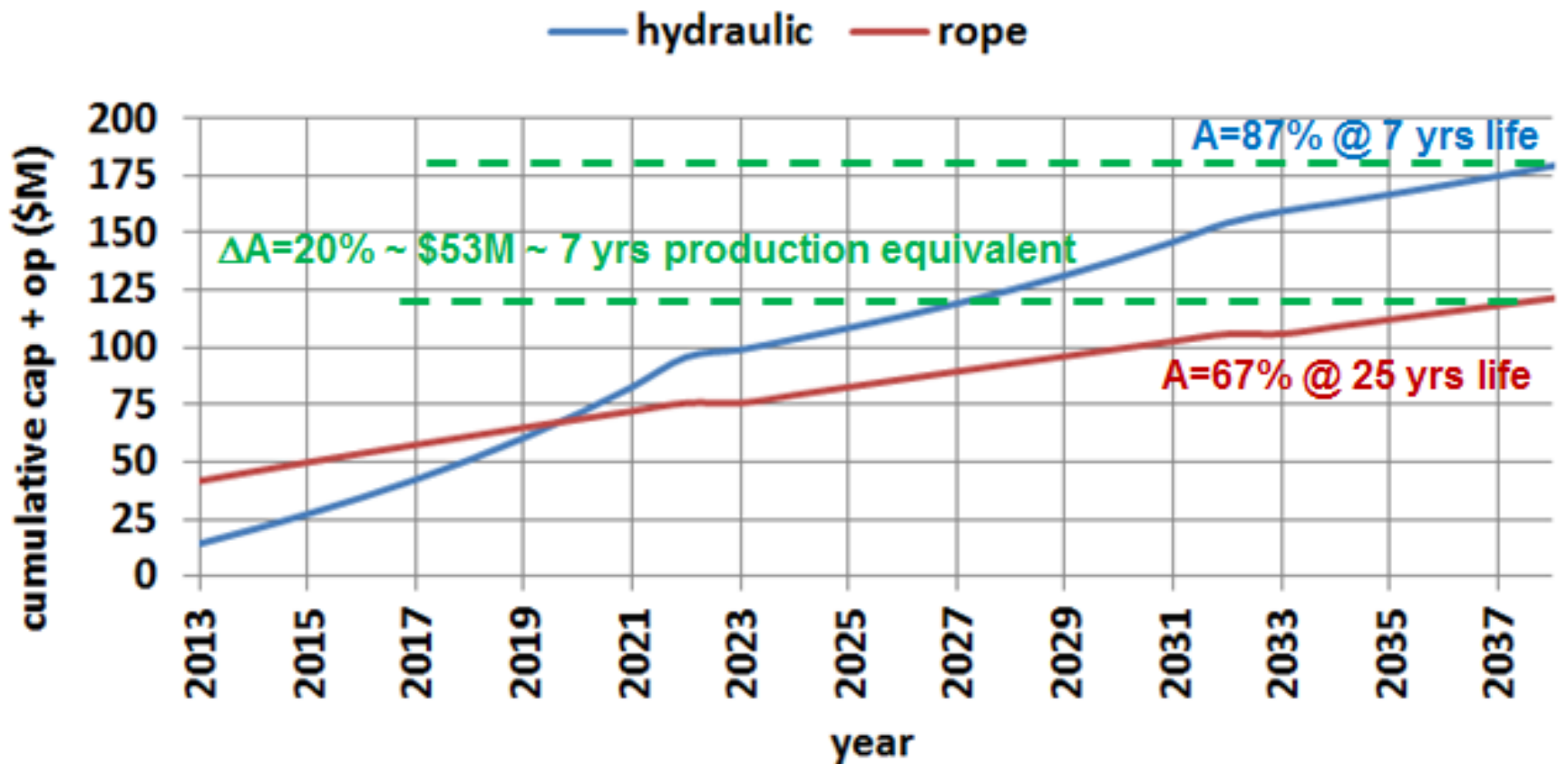


# Comparing operating and maintenance costs

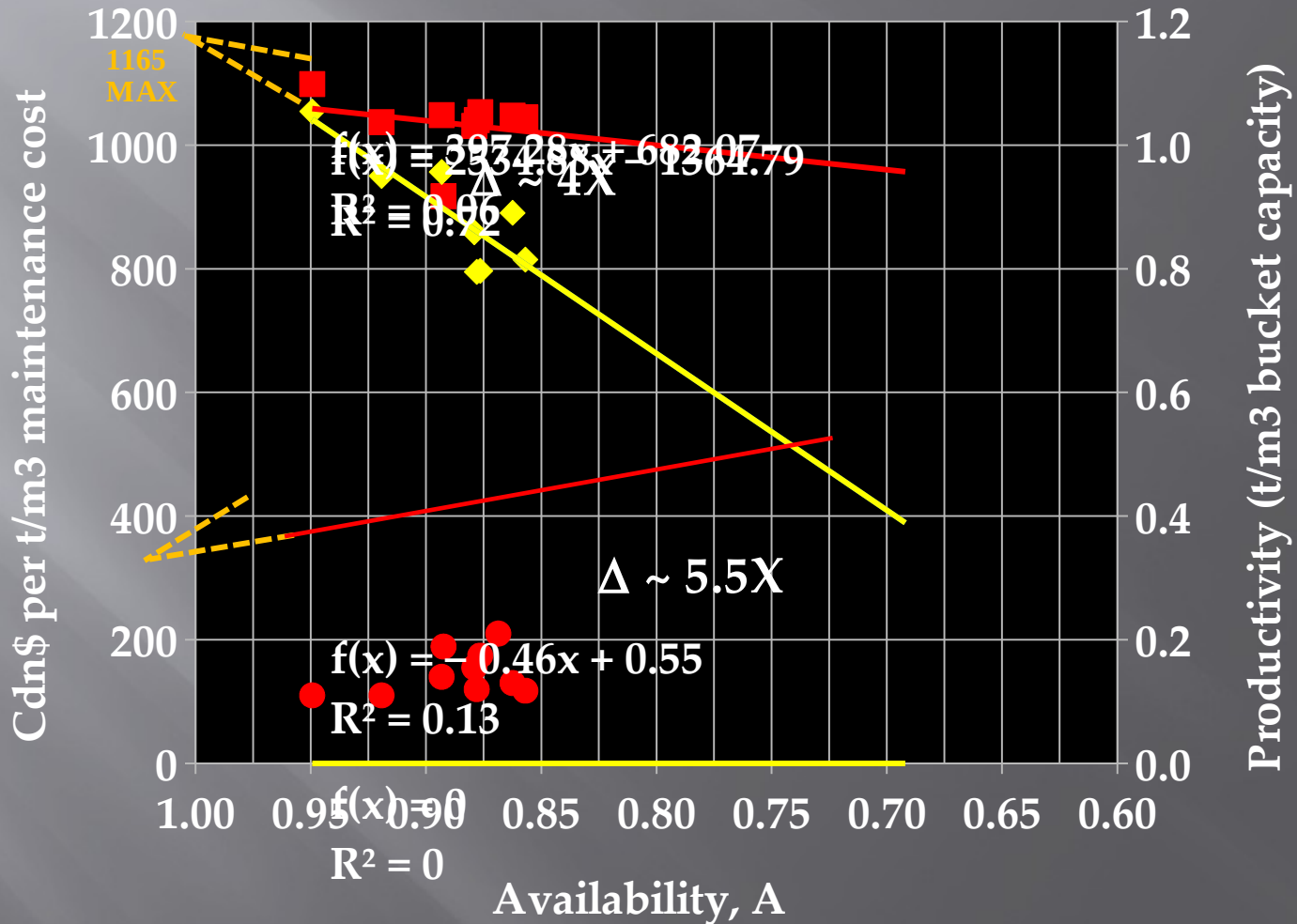
— rope sh. — hyd exc.



# Revisiting the cost of ownership



# Productivity & Maintenance Cost as a function of Availability



# Conclusions



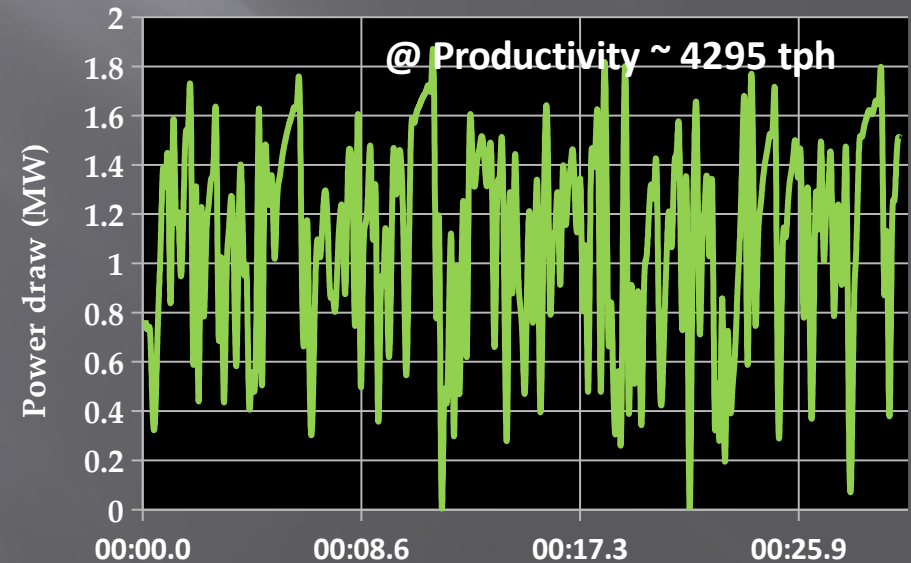
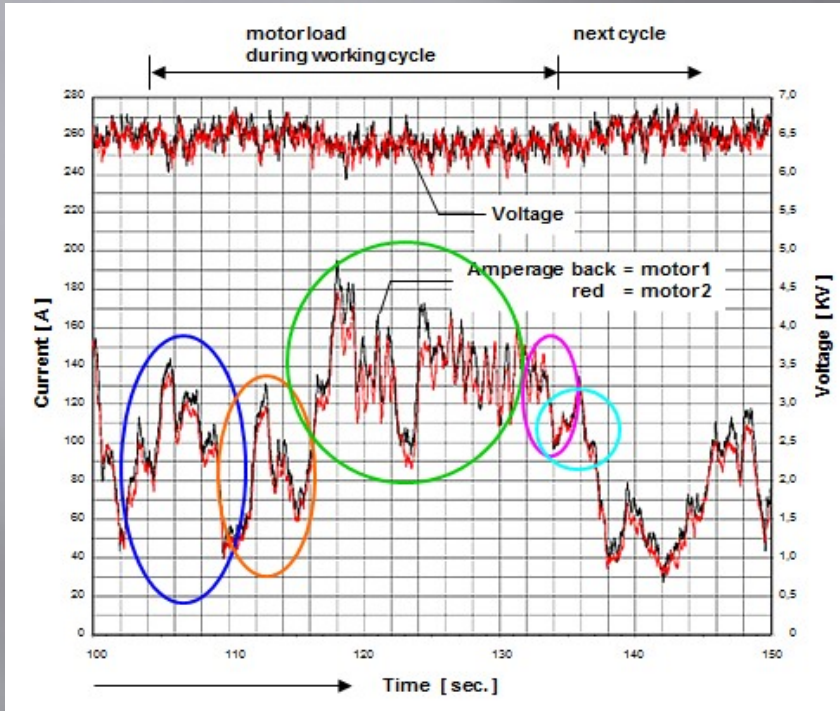
More Q's

for OEMs & users

... coming at H&L 2019



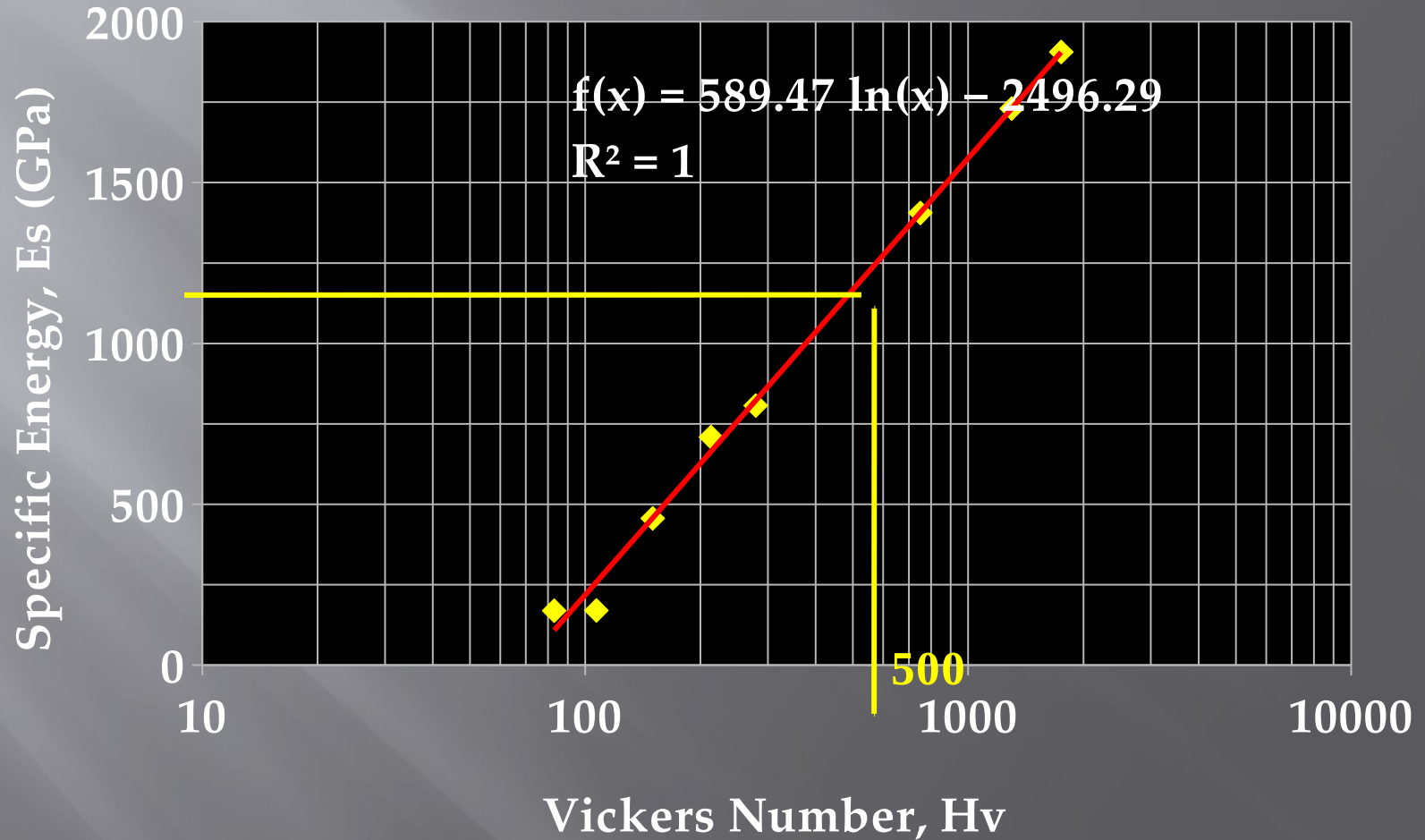
# Impact of blast quality on shovel & crusher - minimizing E used



# Power and Energy per cycle



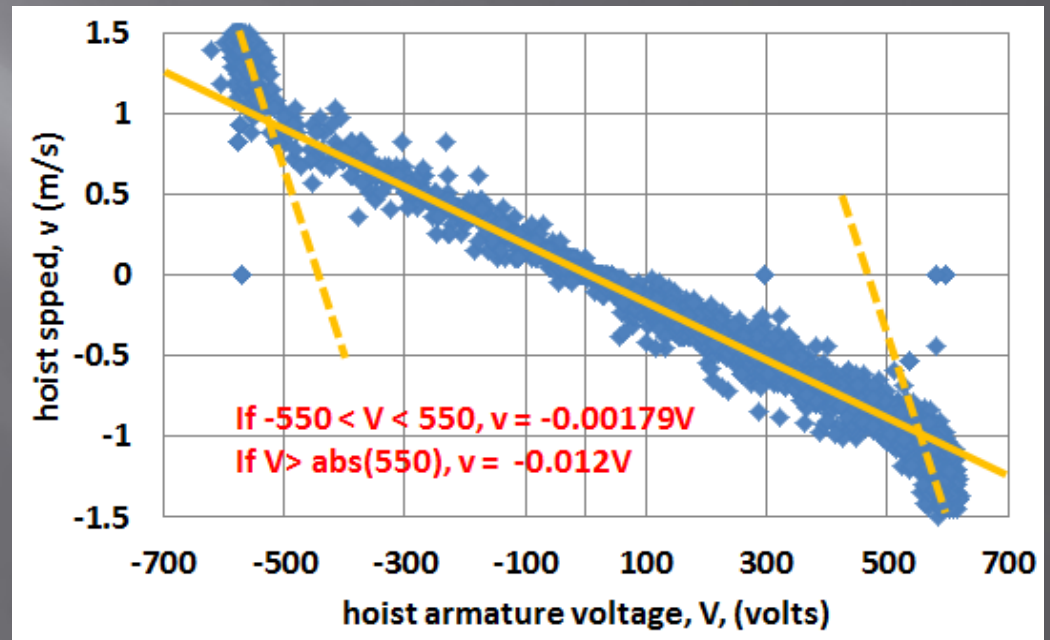
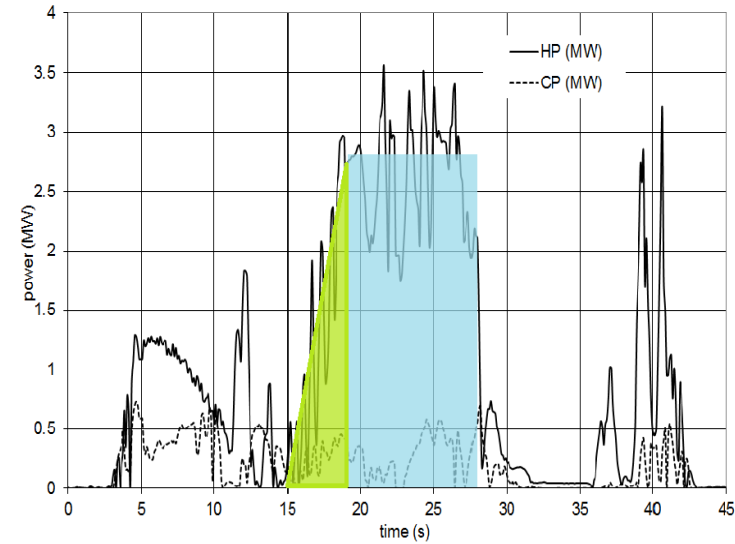
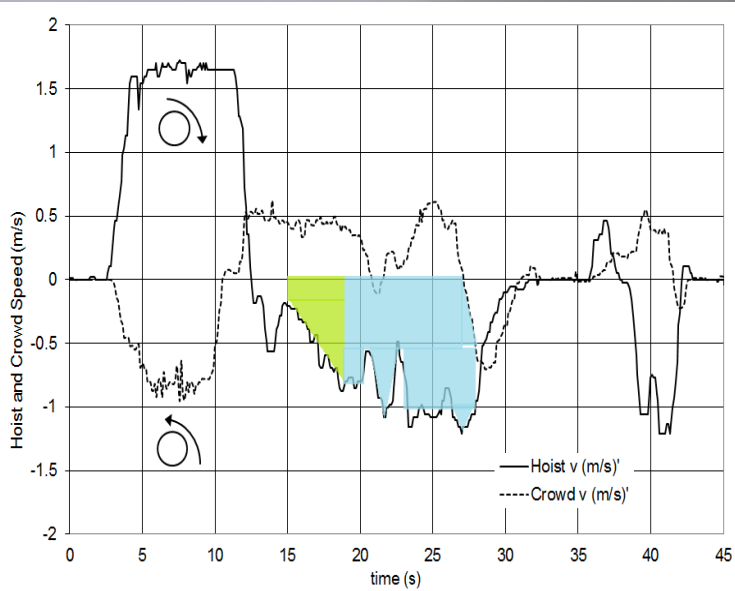
# GET wear = f ( $E_s$ ), Nm/m<sup>3</sup>



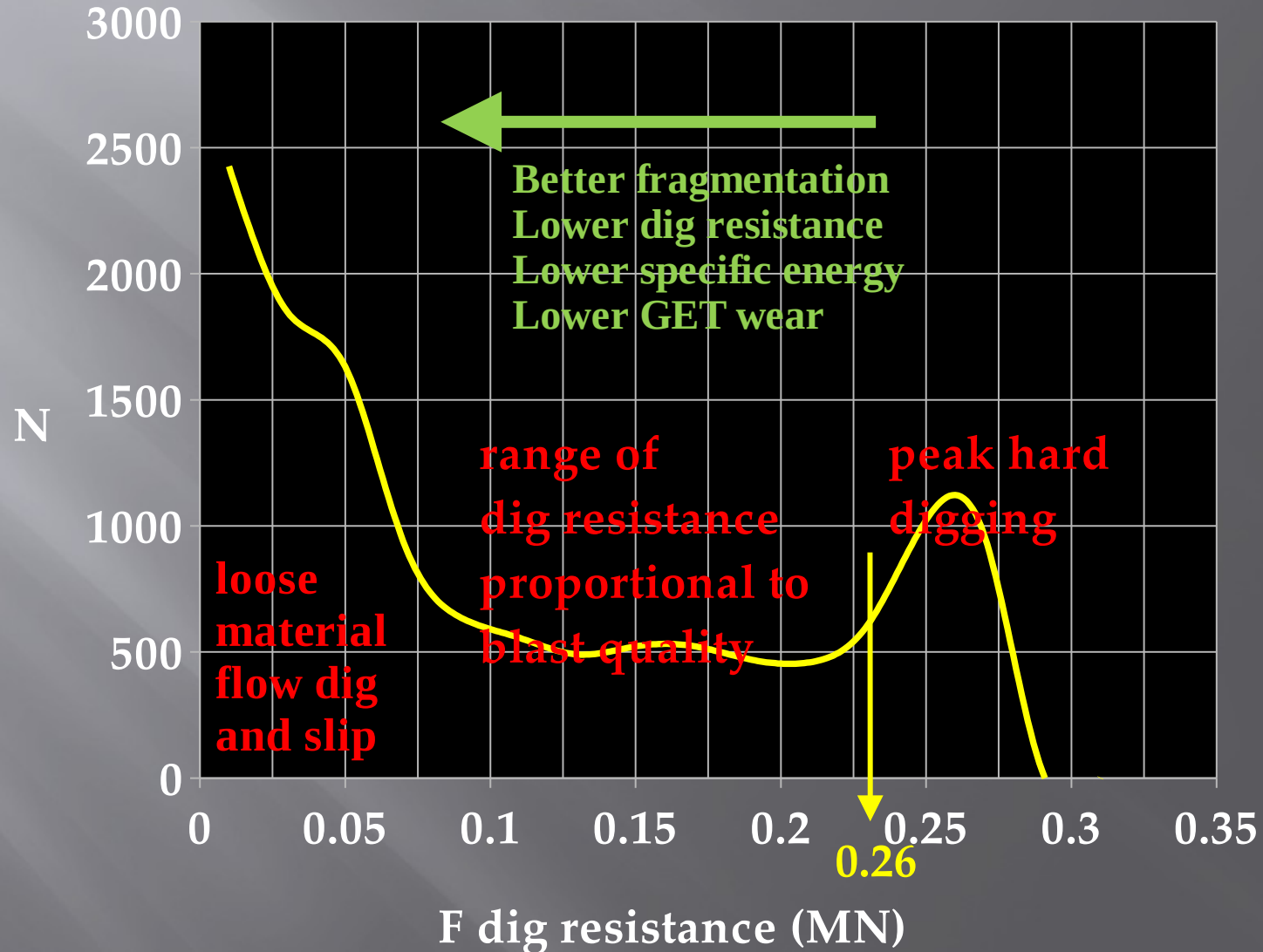
# Predicting tooth wear - example

- 9 tooth lip system
- Duty cycle is ~48 s and shovel has 85% availability and 80% utilization = 3672 cycles
- Energy per cycle = 12.6 MJ
- Wear energy expended per tooth ~ 5140 MJ
- Tooth steel 500 Hv,  $E_s = 1200 \text{ GPa}$  ( $\text{GJ}/\text{m}^3$ )
- **Predict** volume lost =  $5.14/1200 = 0.0043 \text{ m}^3$
- Single shovel tooth **measured** losing 70 lb (31.75 kg, **0.0043 m<sup>3</sup>**) mass in 3 days.

# dig force, $F_{\text{dig}} = \eta P/v$



# Dig force vs. blast quality



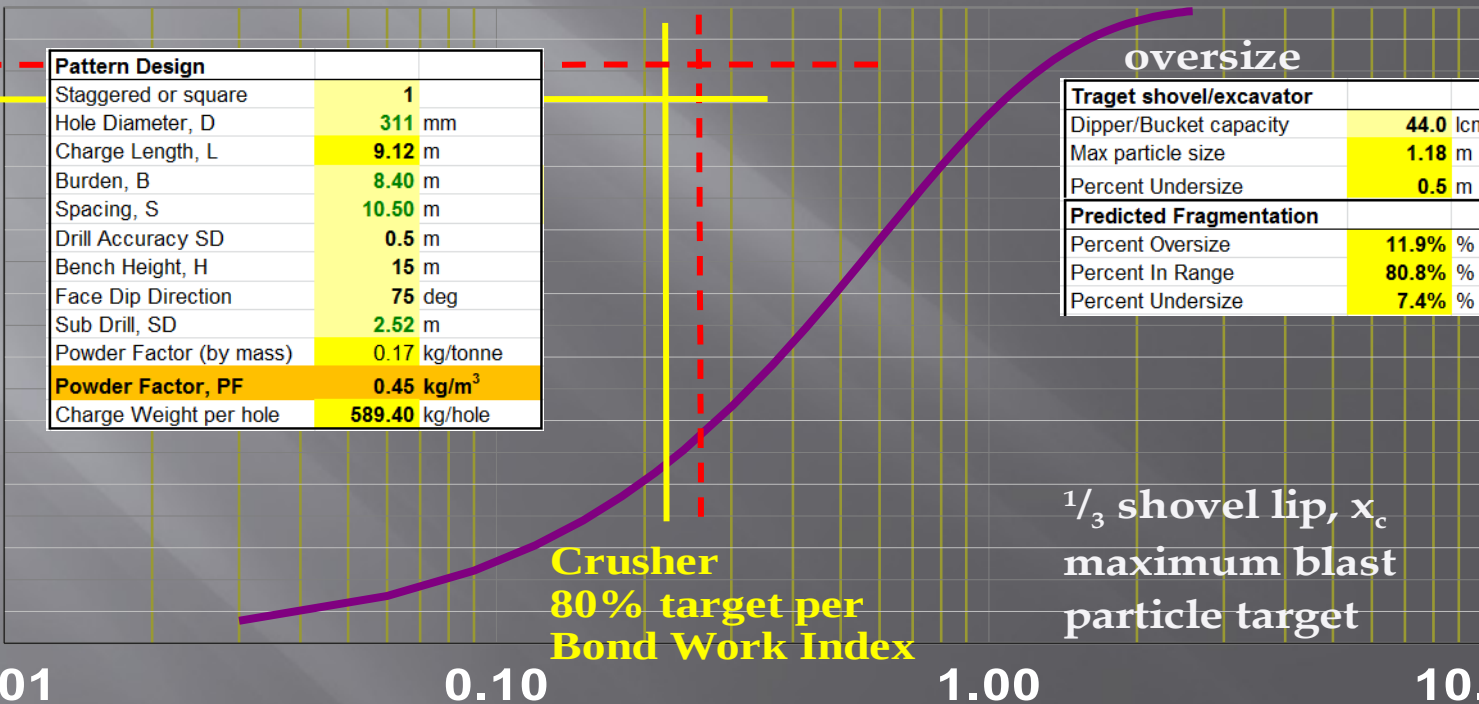
# Fill factor = f(blast & flow)



# Balancing E blast vs. shovel vs. crusher

Percent Passing

100%  
90%  
80%  
70%  
60%  
50%  
40%  
30%  
20%  
10%  
0%



Pattern Design	
Staggered or square	1
Hole Diameter, D	311 mm
Charge Length, L	9.12 m
Burden, B	8.40 m
Spacing, S	10.50 m
Drill Accuracy SD	0.5 m
Bench Height, H	15 m
Face Dip Direction	75 deg
Sub Drill, SD	2.52 m
Powder Factor (by mass)	0.17 kg/tonne
<b>Powder Factor, PF</b>	<b>0.45 kg/m<sup>3</sup></b>
Charge Weight per hole	589.40 kg/hole

Traget shovel/excavator	
Dipper/Bucket capacity	44.0 lcm
Max particle size	1.18 m
Percent Undersize	0.5 m
Predicted Fragmentation	
Percent Oversize	11.9% %
Percent In Range	80.8% %
Percent Undersize	7.4% %

Crusher  
80% target per  
Bond Work Index

1/3 shovel lip,  $x_c$   
maximum blast  
particle target

Size (m)



# Conclusions



Next time – see you at H&L 2019