Crushing
- Optimizing the Process

QUARRY ACADEMY

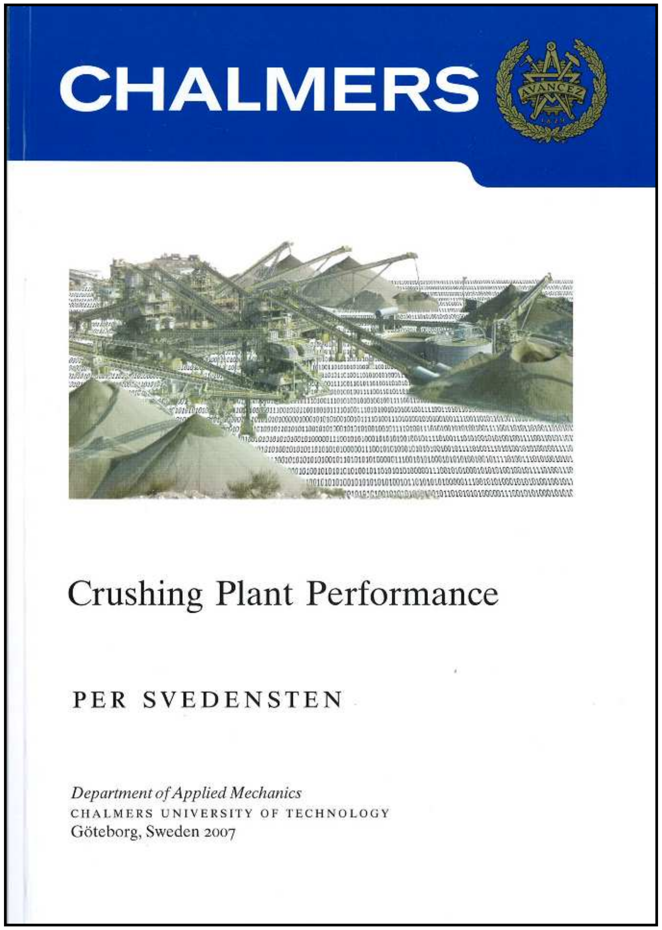
Improving Processes. Instilling Expertise.

DYNO
Dyno Nobel

SANDVIK

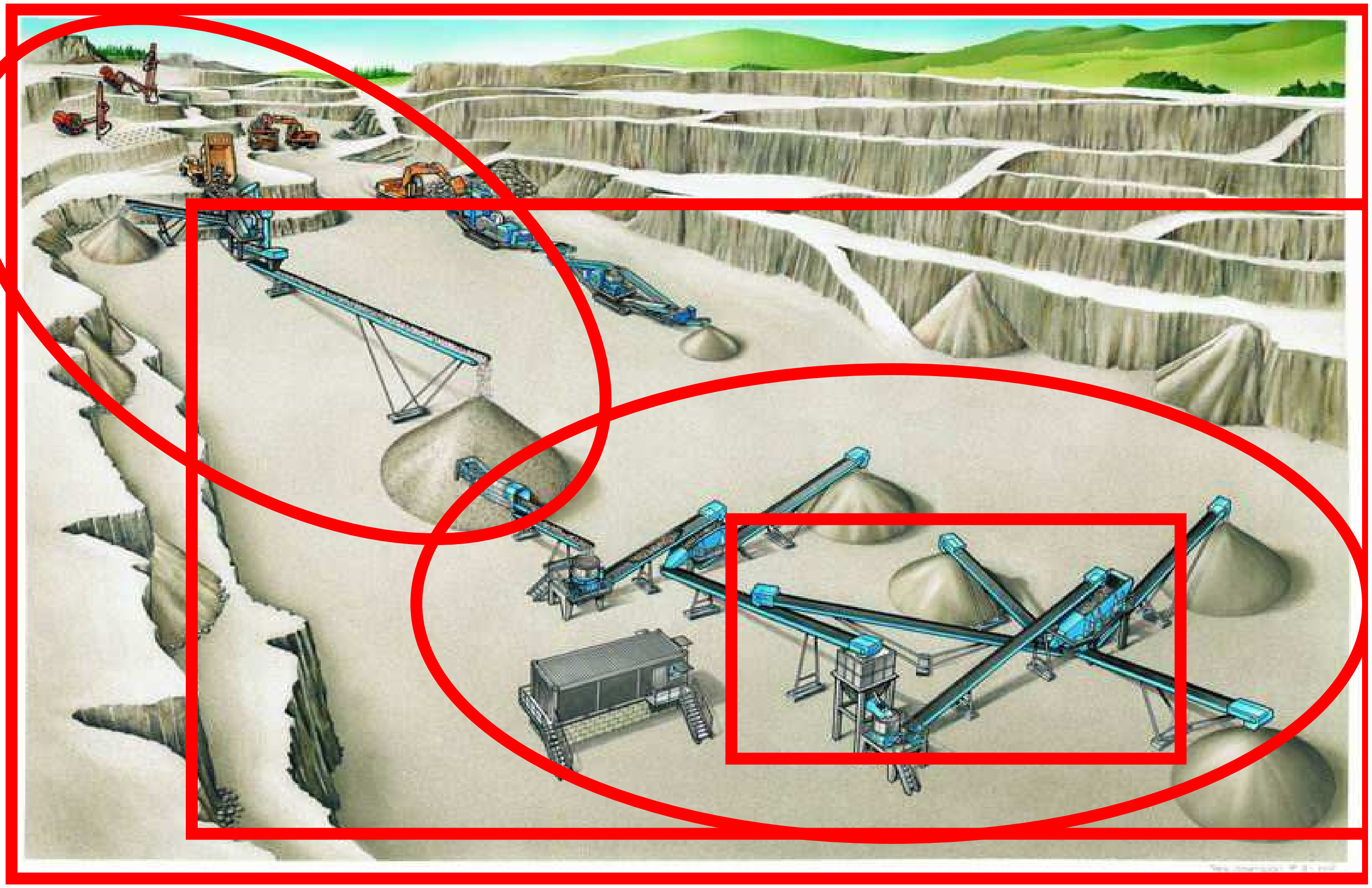
Optimizing the Process

- Methods to combine and simulate technical and economic performance
- Optimum crushing plant performance is difficult to achieve due the process characteristics. Different compared to all other industrial processes.
- Optimizing method for best performance
- Partly implemented in PlantDesigner 10



Crushing Plant Optimization

- Point of interest
  - ✓ Crushing stage
  - ✓ Crushing plant
  - ✓ Quarry Process
- Today:
  - ✓ Optimize the feed
  - ✓ Optimize the process



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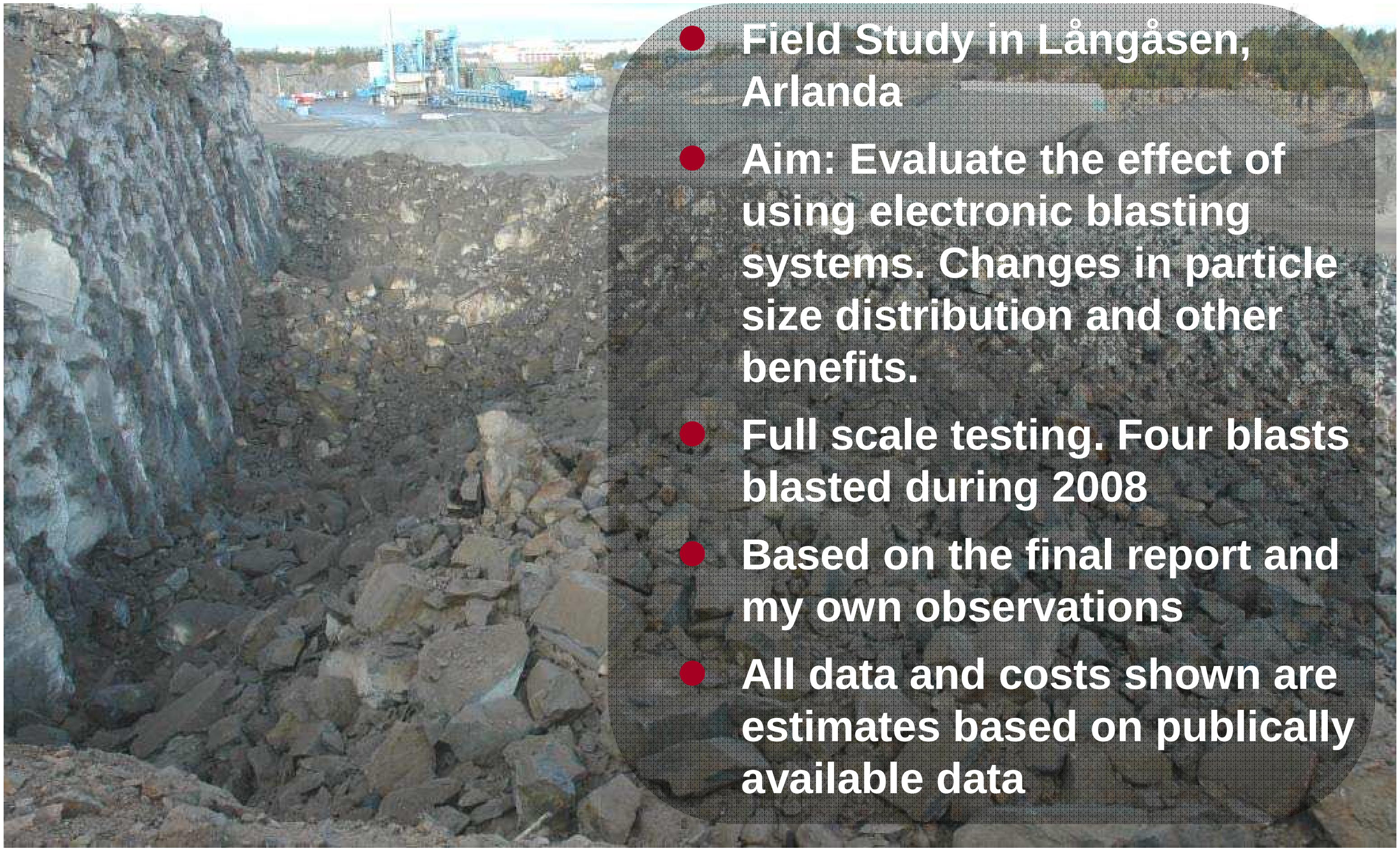
MinBaS II
Optimized blasting

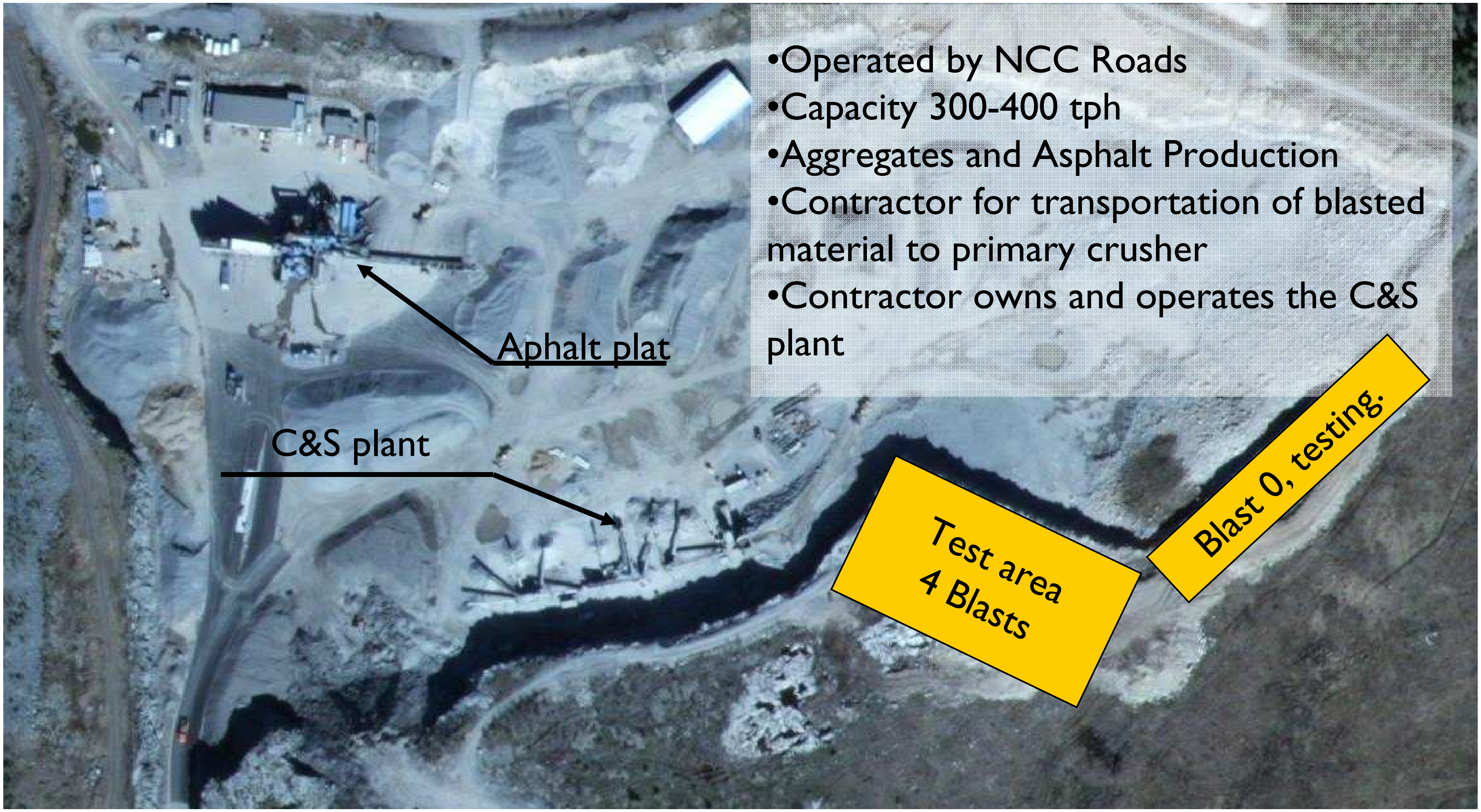


- Field Study in Långåsen, Arlanda
- Aim: Evaluate the effect of using electronic blasting systems. Changes in particle size distribution and other benefits.
- Full scale testing. Four blasts blasted during 2008
- Based on the final report and my own observations
- All data and costs shown are estimates based on publically available data

The Study

- Comparisons between the cost and earnings for different blasting strategies.
- Conclusions and recommendations

The Quarry
Långåsen, Arlanda



- Operated by NCC Roads
- Capacity 300-400 tph
- Aggregates and Asphalt Production
- Contractor for transportation of blasted material to primary crusher
- Contractor owns and operates the C&S plant

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Blasted Material
Test plan

Blast 1	**None Electric**	**None Electric**
	1.35 lb/yd^3	1.85 lb/yd^3
Blast 2	**None Electric**	**None Electric**
	1.85 lb/yd^3	1.35 lb/yd^3
Blast 3	**Electronic Blasting System**	
	1.35 lb/yd^3 10 ms between holes	
Blast 4	**Electronic Blasting System**	
	1.35 lb/yd^3 5 ms between holes	

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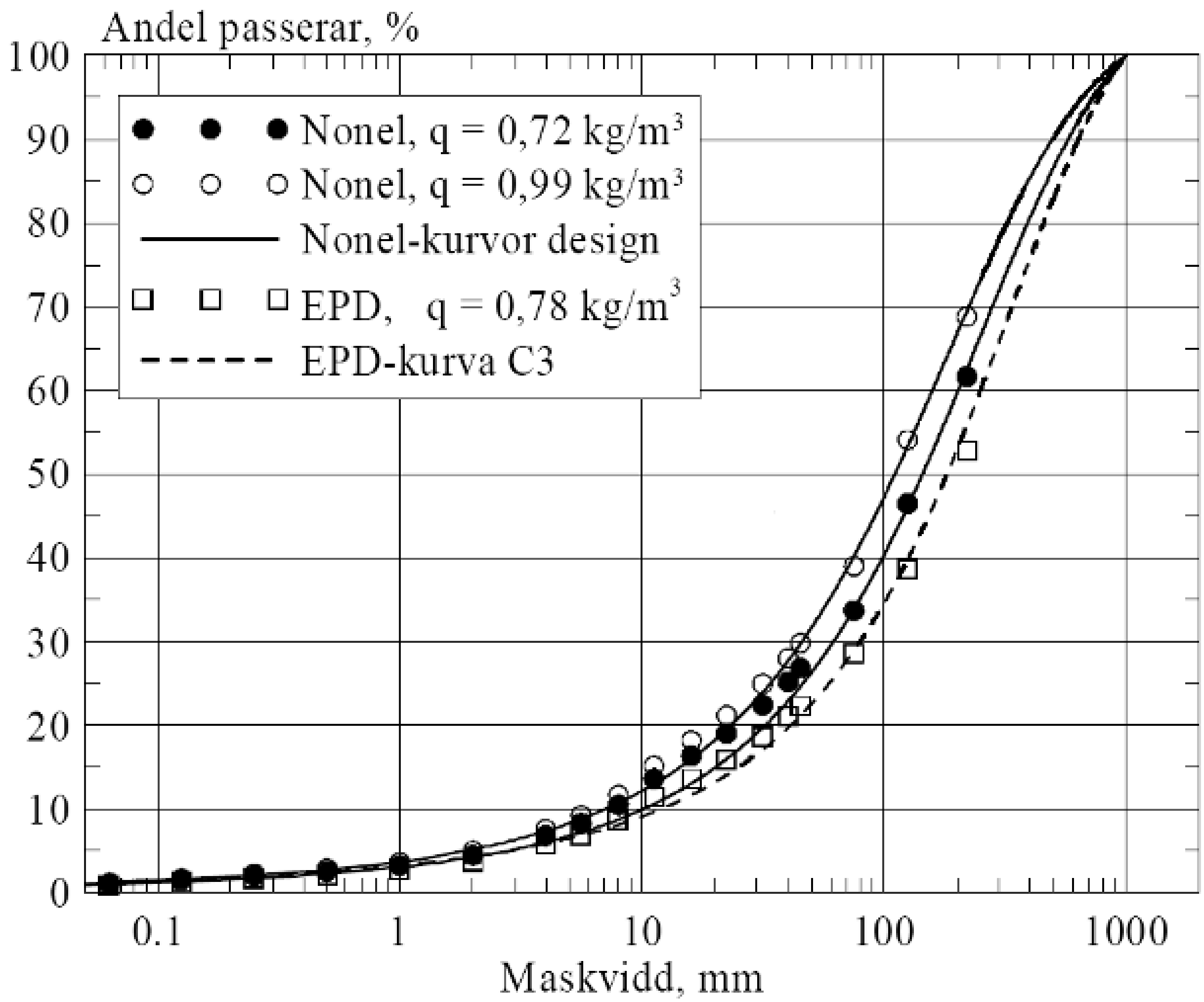
Blasting result
Measuring the Particle Size Distribution



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Blasting result
Cost analysis

	Nonel norm. q [$/ton*]	Nonel high q [$/ton*]	EPD norm. q [$/ton*]
Drilling and Blasting	0.90	1.23	0.97
Added cost for detonators	0,00	0,00	0.30
Bolder Management	0.30	0.15	0.22
Sum	1.20	1.38	1.49

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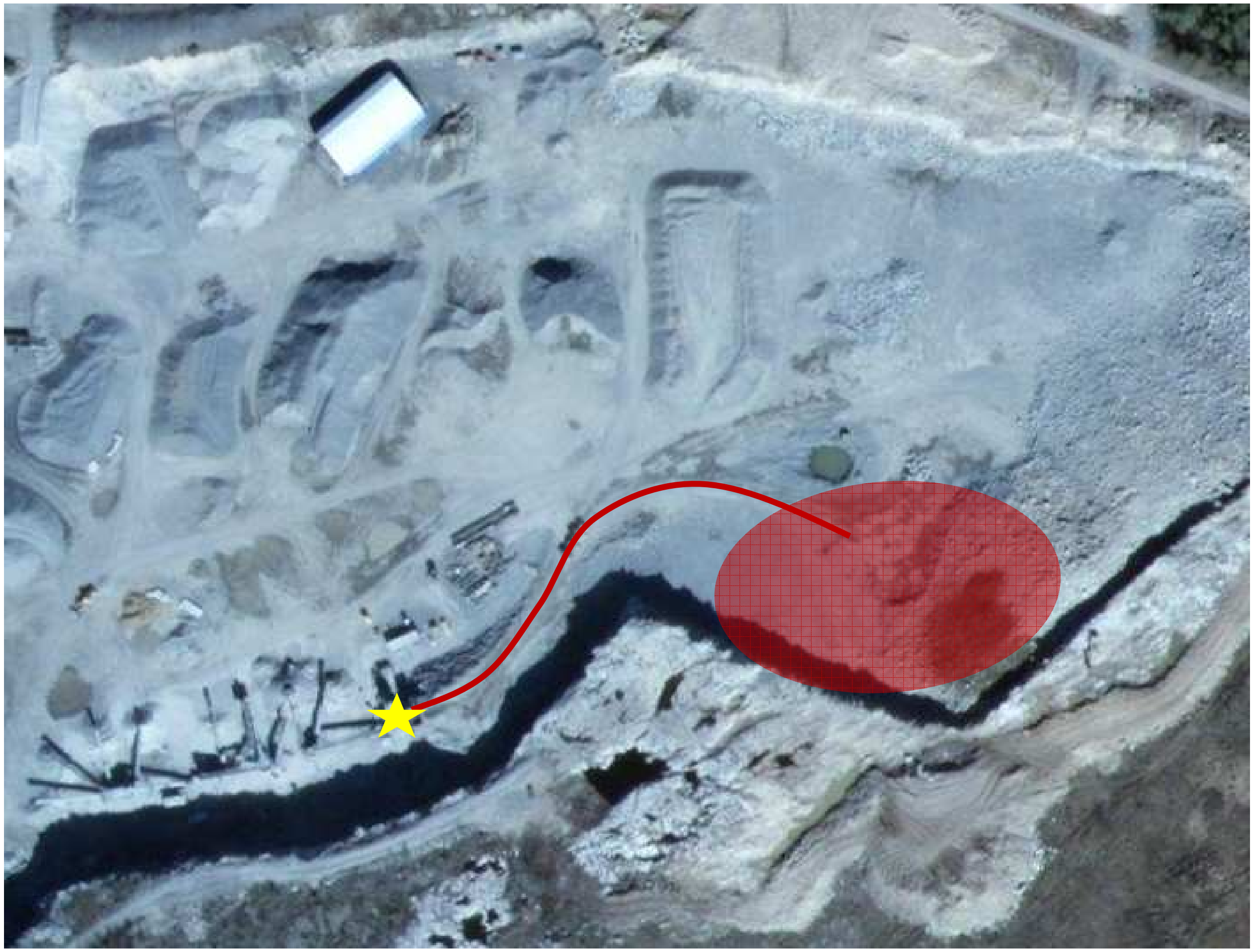
*Estimates based on publicly available data

Loading and Hauling Conditions and Measurments

- **Loading and Hauling to primary crusher**
  - ✓ **Wheel loader carries the material from the muck pile to the crusher**
- **Conducted studies**
  - ✓ **Measurment of wheel loaded loading times**
  - ✓ **Measurment of loaded material [tph]**
  - ✓ **Manual timing during several days**



Loading and Hauling
Cost analysis

	Nonel norm. q	Nonel high q	EPD norm. q
Contractor [$/h*]	**448**	**448**	**448**
Loading Capasity [tph]	**298**	**316**	**313**
Cost [$/ton]	**1.50**	**1.42**	**1.43**
Sum incl Drilling and Blasting [$/ton]	1.20+1.50= =2.70	1.38+1.42= =2.80	1.49+1.43= =2.92

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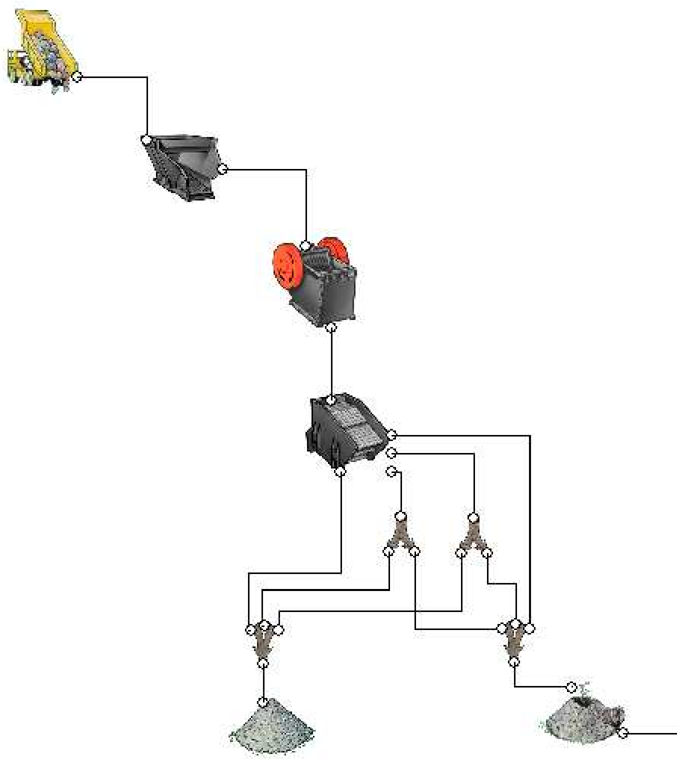
*Estimates based on publicly available data

Crushing and Screening
Plant Setup and Conditions for the Study



0-3.5” (0-90 mm)

+3.5” (+90 mm)

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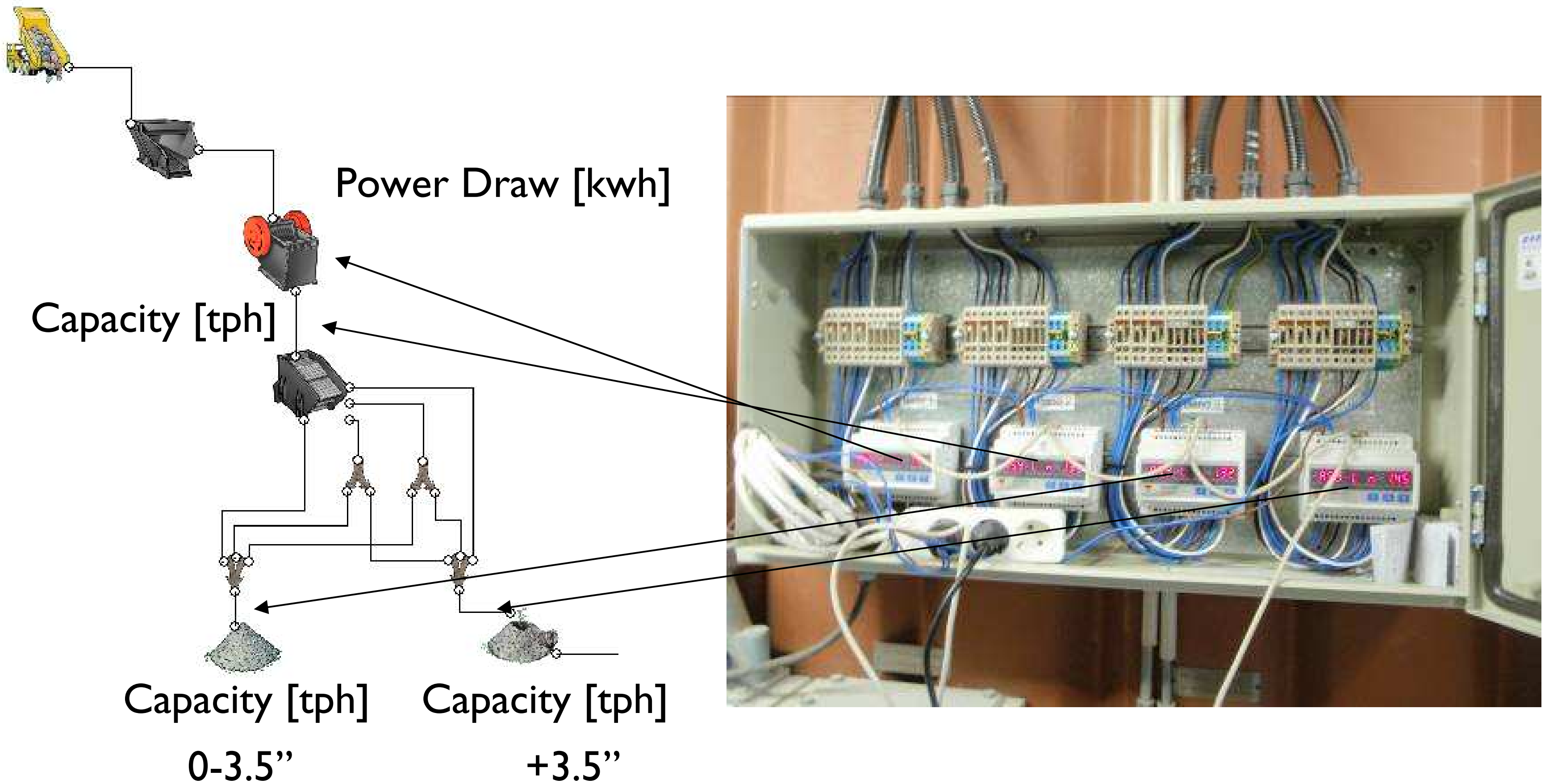
Crushing and Screening Performed Measurements



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Crushing and Screening
Cost analysis

	Nonel norm. q	Nonel high q	EPD norm. q
Power Draw (kWh/ton)	0.3	0.25	0.35
Energy Cost (0.30 $/kWh)*	0.09	0.07	0.10
Fixed Cost [$/h] [$/ton]	746 2.41	746 2.29	746 2.28
Cost [$/ton]	2.50	2.36	2.38
Sum incl D&B och L&H [$/ton]	1.20+1.50+2.50= = 5.20	1.38+1.42+2.36= = 5.16	1.49+1.43+2.38= = 5.30

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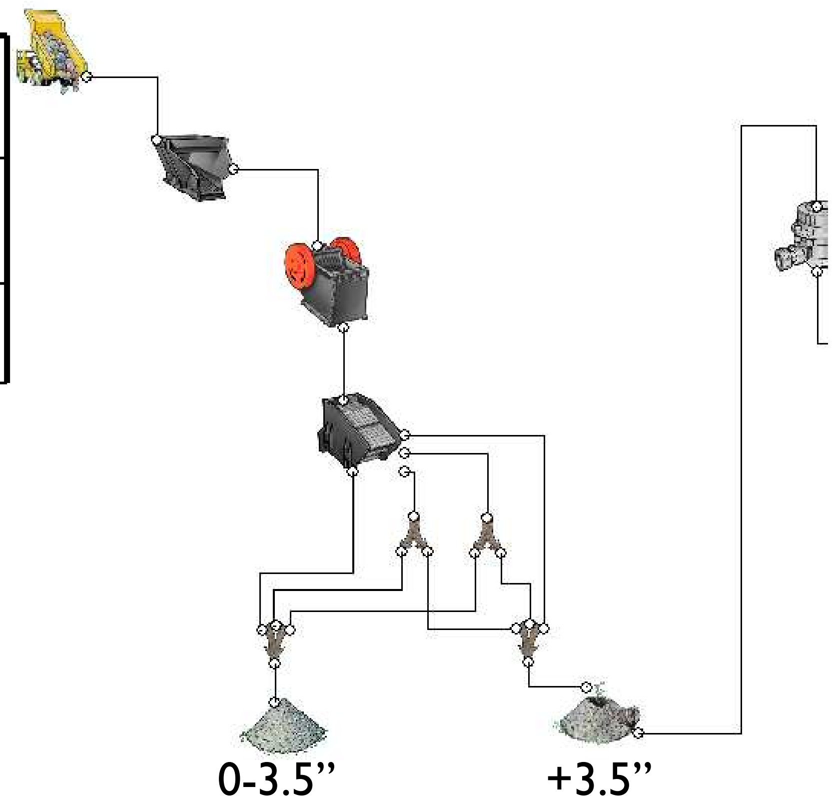
*Estimates based on publicly available data

Production
Total cost $/h

	Nonel norm. q	Nonel high q	EPD norm. q
Production rate [tph]	298	316	313
Cost [$/h]	1600	1676	1723



Distribution between 0-3.5” and +3.5” is partly controlled by the blasting result

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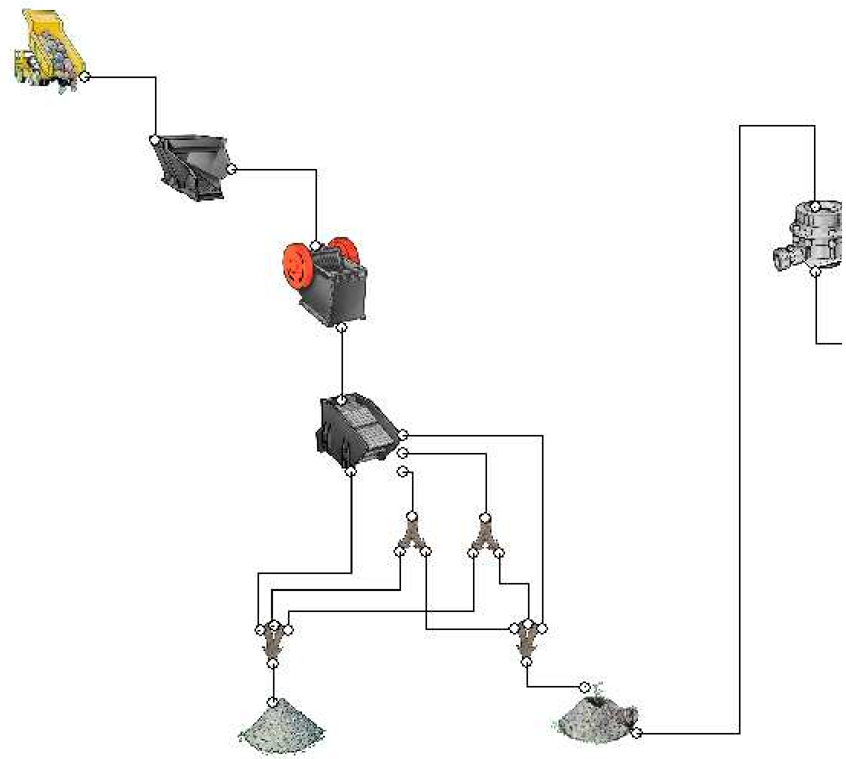
Procution
Product Price

Fraction [mm]	Price [$/ton]	Crushing stage	Ave. Price [$/ton]
0-90	11.94	1 (Prim.)	11.94
0-4	19.25	3-4	21.19
4-8	20.75		
8-11	23.73		
11-16	22.53		
16-32	20.15		



0-3.5” +3.5”

11.94 $/ton 21.19 $/ton

*Estimates based on publicly available data

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Production
Revenue sek/h

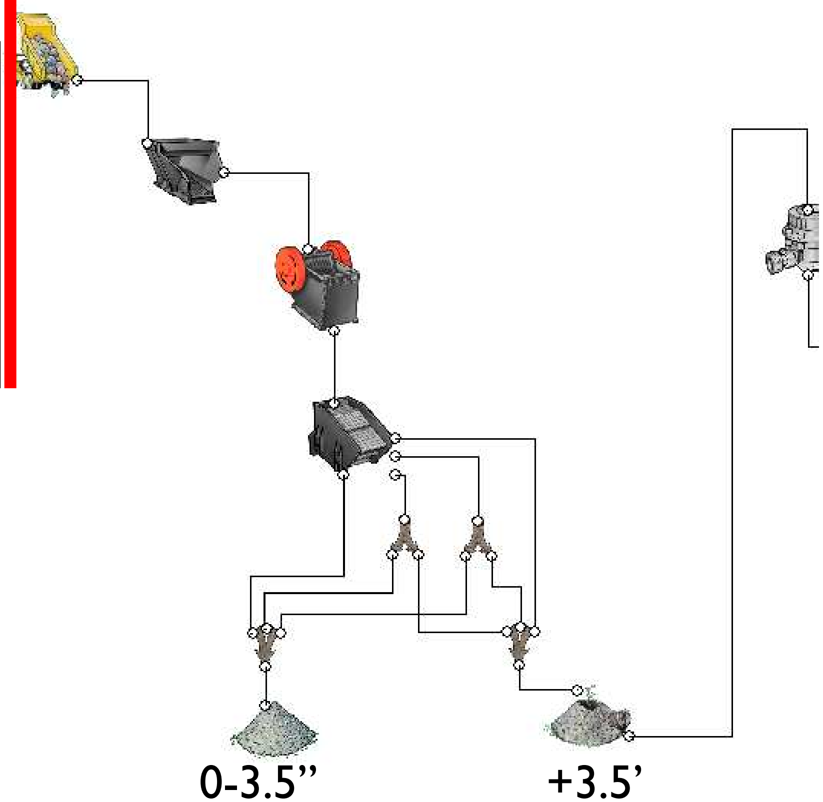
	Nonel normalt q	Nonel high q	EPD normalt q
Produktion [tph]	**298**	**316**	**313**
Produktion 0-3.5’’ [tph]	**186**	**206**	**189**
Price 0-3.5’’ $/ton*	**11.94**	**11.94**	**11.94**
Produktion +3.5’’ [tph]	**112**	**110**	**124**
Ave. Price +3.5’’ $/ton*	**21.19**	**21.19**	**21.19**
Revenue $/h	4595	4791	4885

*Estimates based on publicly available data

Production
Cost and Revenue*

	Nonel norm. q	Nonel high q	EPD norm. q
Production rate [tph]	298	316	313
Cost [$/h]	1343	1412	1425

Minimizing cost does not necessarily maximize profit



Distribution between 0-3.5” and +3.5” is partly controlled by the blasting result

*Based on publicly available data

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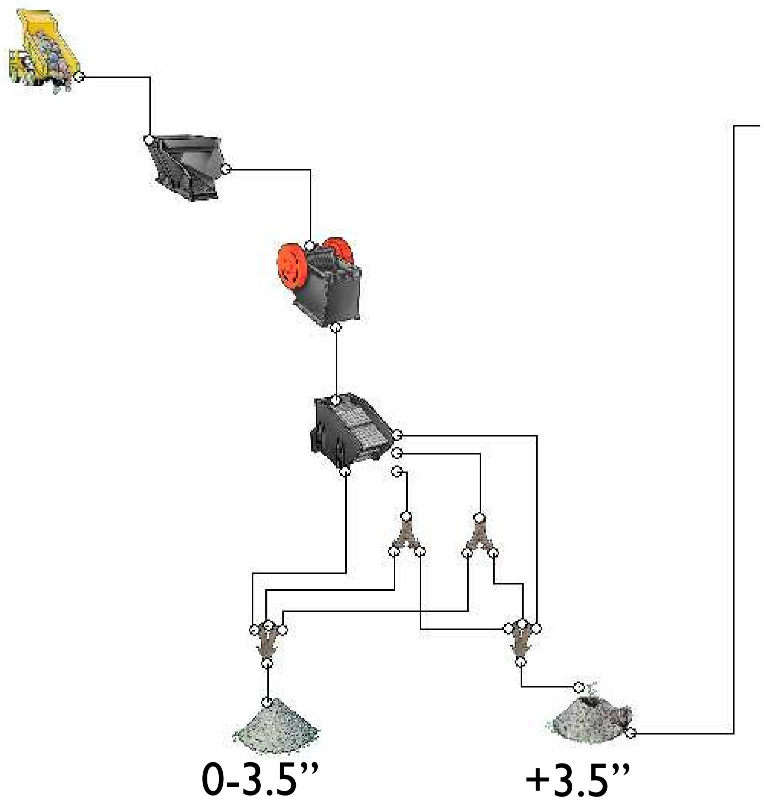
Conclusions

- **From the tested blasting alternative Electronic Blasting System is the most beneficial.**
- **Extensive investigations and analysis are necessary in order to determine the optimal solution. Many areas are effected by the blasting result.**
  - ✓ **Drilling and Blasting**
  - ✓ **Bolder Management**
  - ✓ **Loading and Hauling**
  - ✓ **Crushing and Screening**
- **Only studying the costs is not sufficient in order to optimize the process. Most expensive solution did also generate the most profit.**

Conclusions – Guidance for previous processes

- **Feed to the primary crusher matters more then just boulders**
- **The effect of different feed gradations (blast results) are difficult to detect without measuring actively.**
- **Communicate effects upwards in the process**



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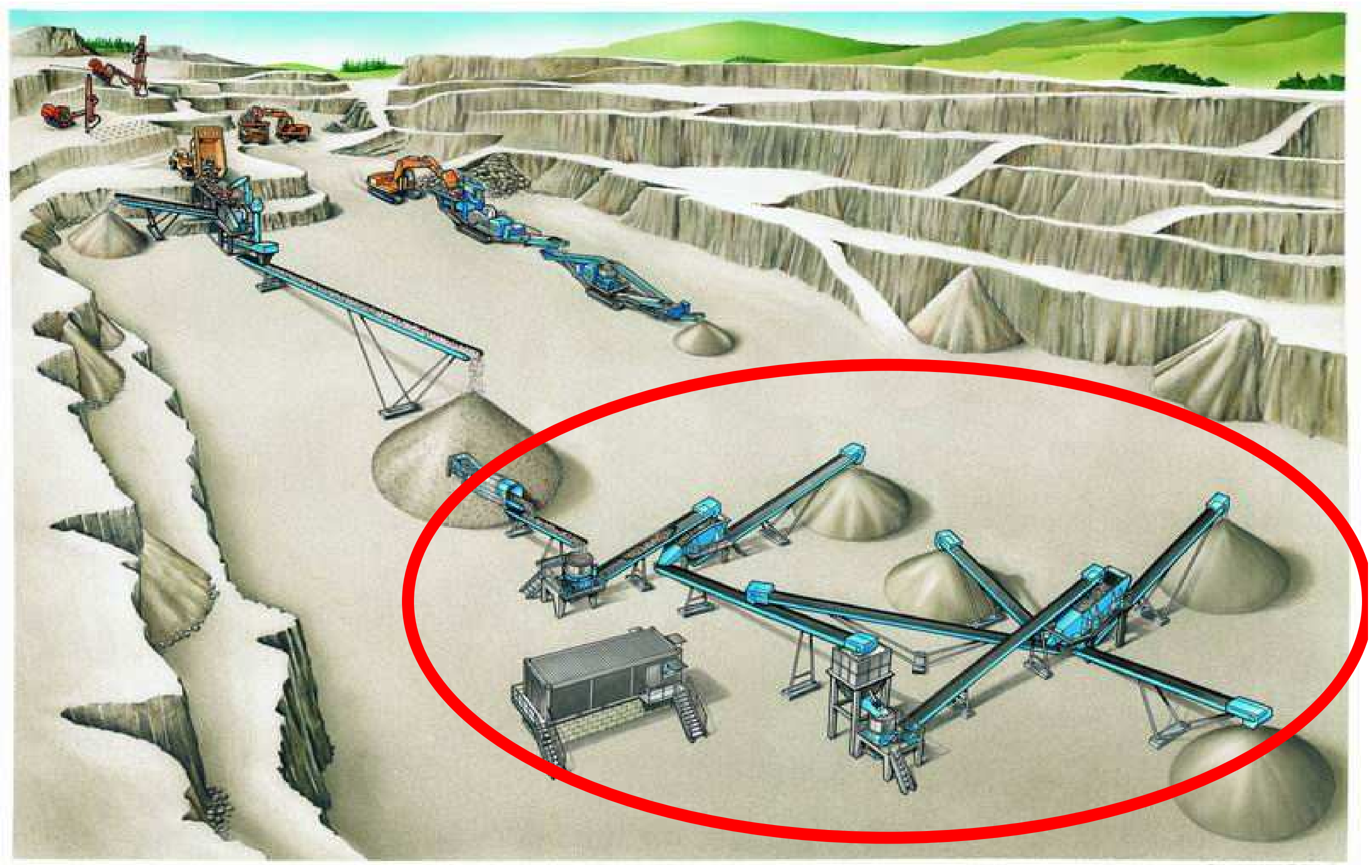
What about Optimizing the Crushing and Screening Process?

- Optimizing a single crusher can be done manually as seen earlier
- Optimizing several crushers?
  - ✓ Combination of equipment setting
  - ✓ Production situation, what products are demanded and what are not?



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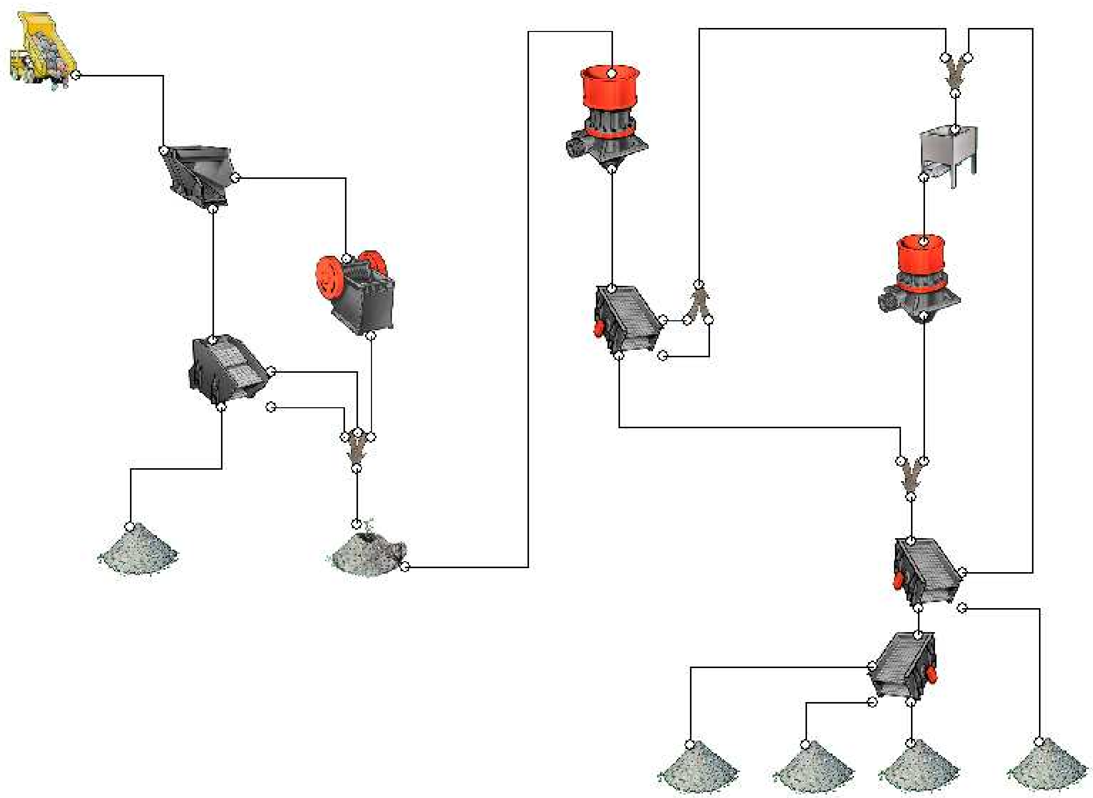
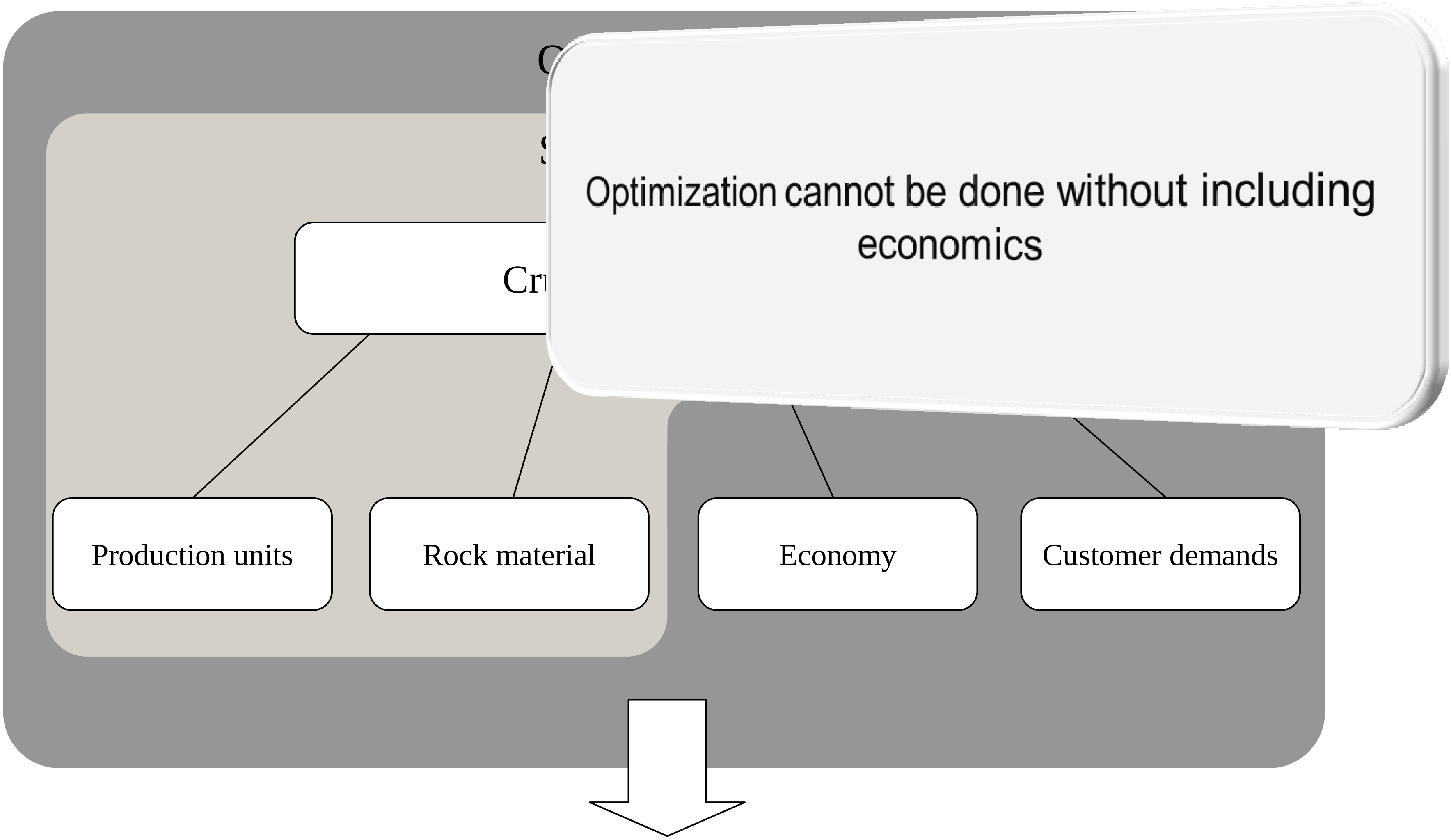
Crushing plant optimization using TCO Objective of project

- To optimize the crushing plant using computer optimization
- Use sampling to calibrate the computer model in order to increase model accuracy
- Optimize with the goal to maximize gross profit



Modelling



Yield the most profitable production strategy and meet the market demand

Crushing plant optimization using TCO Calculation approach

- Included in cost the calculation
  - ✓ Raw material
  - ✓ Depreciation
  - ✓ Interest
  - ✓ Energy cost
  - ✓ Wear parts replacement
  - ✓ Service cost
  - ✓ By-product production
  - ✓ Personnel

- Income calculation
  - ✓ Sellable products
  - ✓ Product demand

- Other factors included that effects the gross profit
  - ✓ Availability
  - ✓ Utilization

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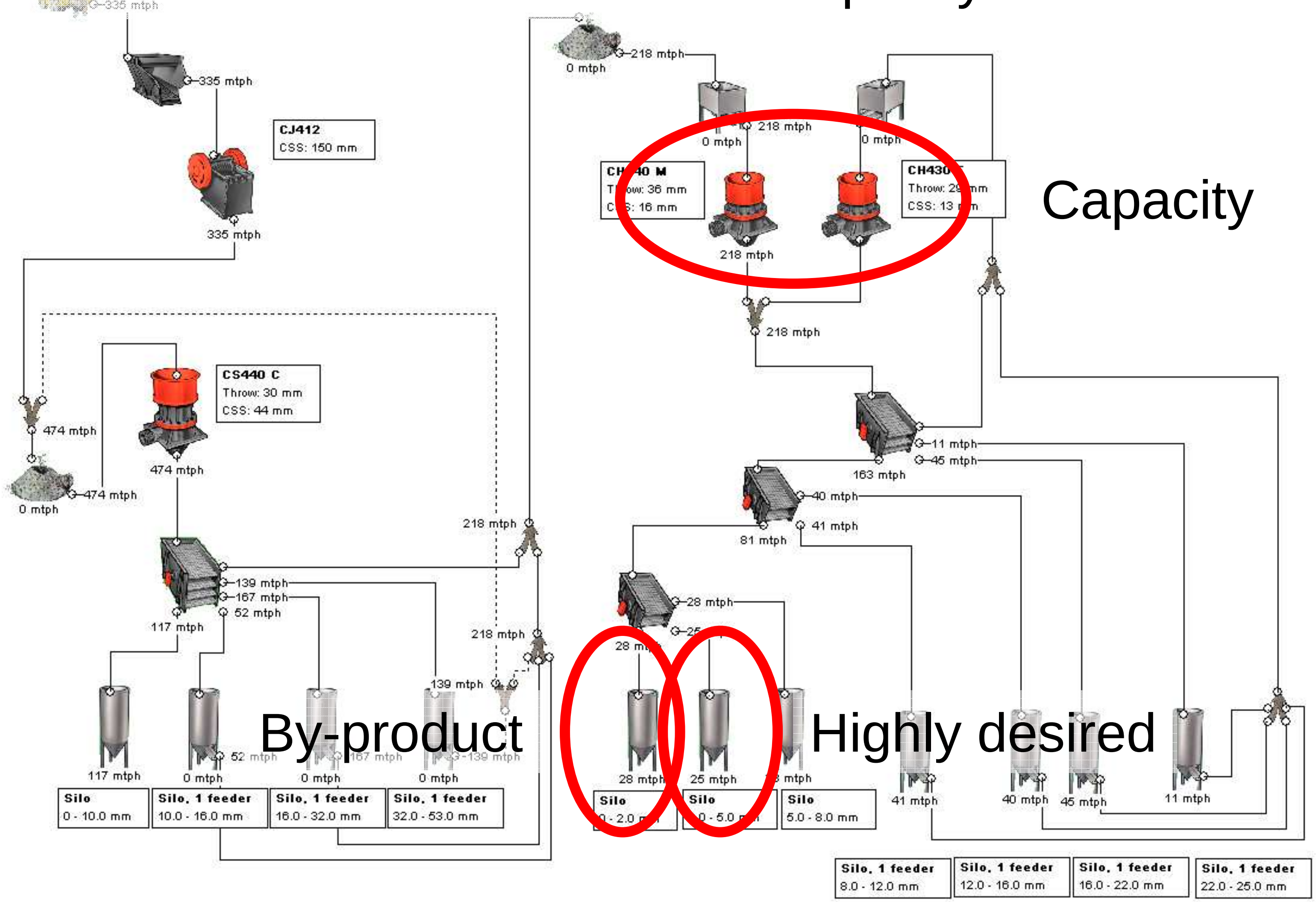
Crushing plant optimization using TCO
Plant Challenges

What is the best trade-off between capacity and reduction?



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Crushing plant optimization using TCO
Test plant

In normal production following CSS are utilized:

Secondary crusher – CSS 44 mm 1.73''

Tertiary crusher – CSS 16 mm 0.63''

Quaternary crusher – CSS 13 mm 0.51''

Products:

0-2 mm

2-5 mm

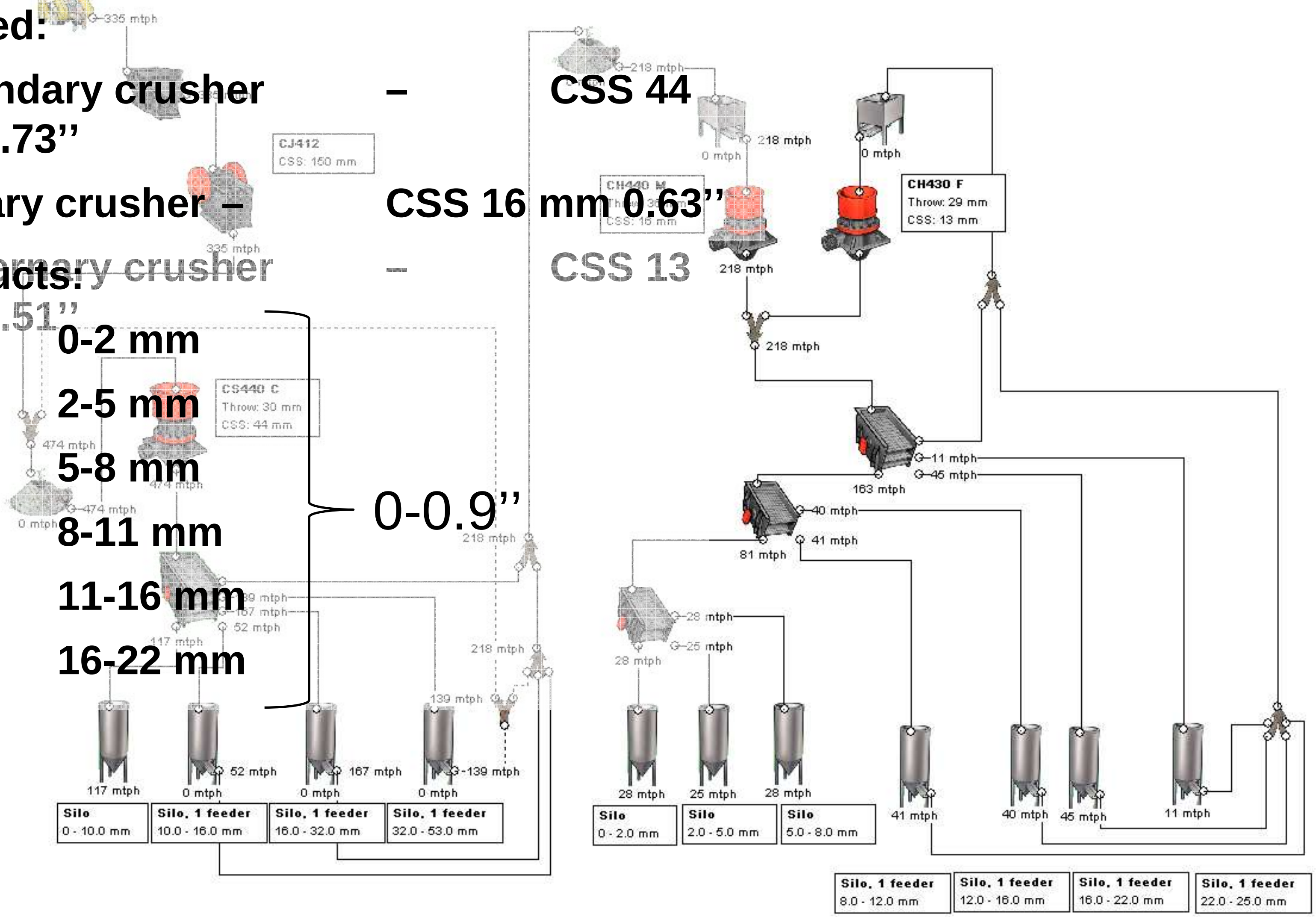
5-8 mm

8-11 mm

11-16 mm

16-22 mm

} 0-0.9''



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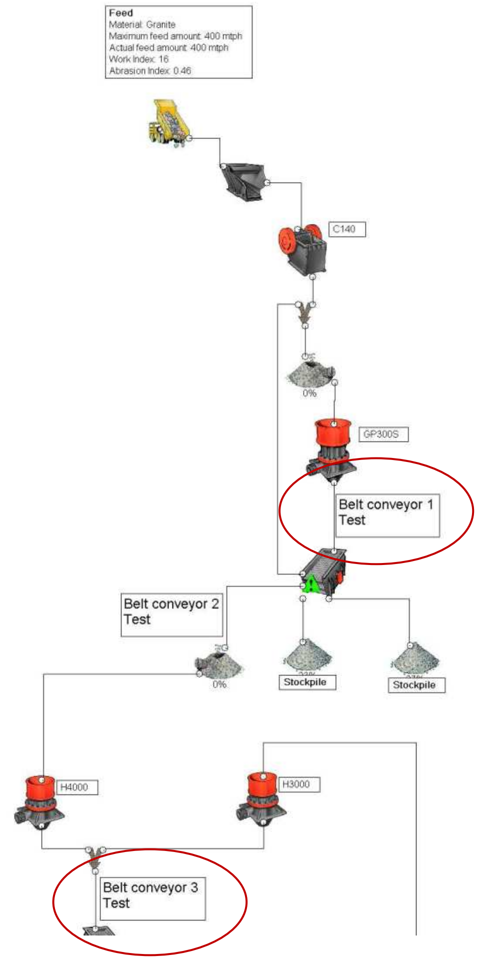
Crushing plant optimization using TCO Test plan

Objectives for the first test session:

- **Measure particle size distribution to calibrate t simulation model**
- **CSS at original settings**



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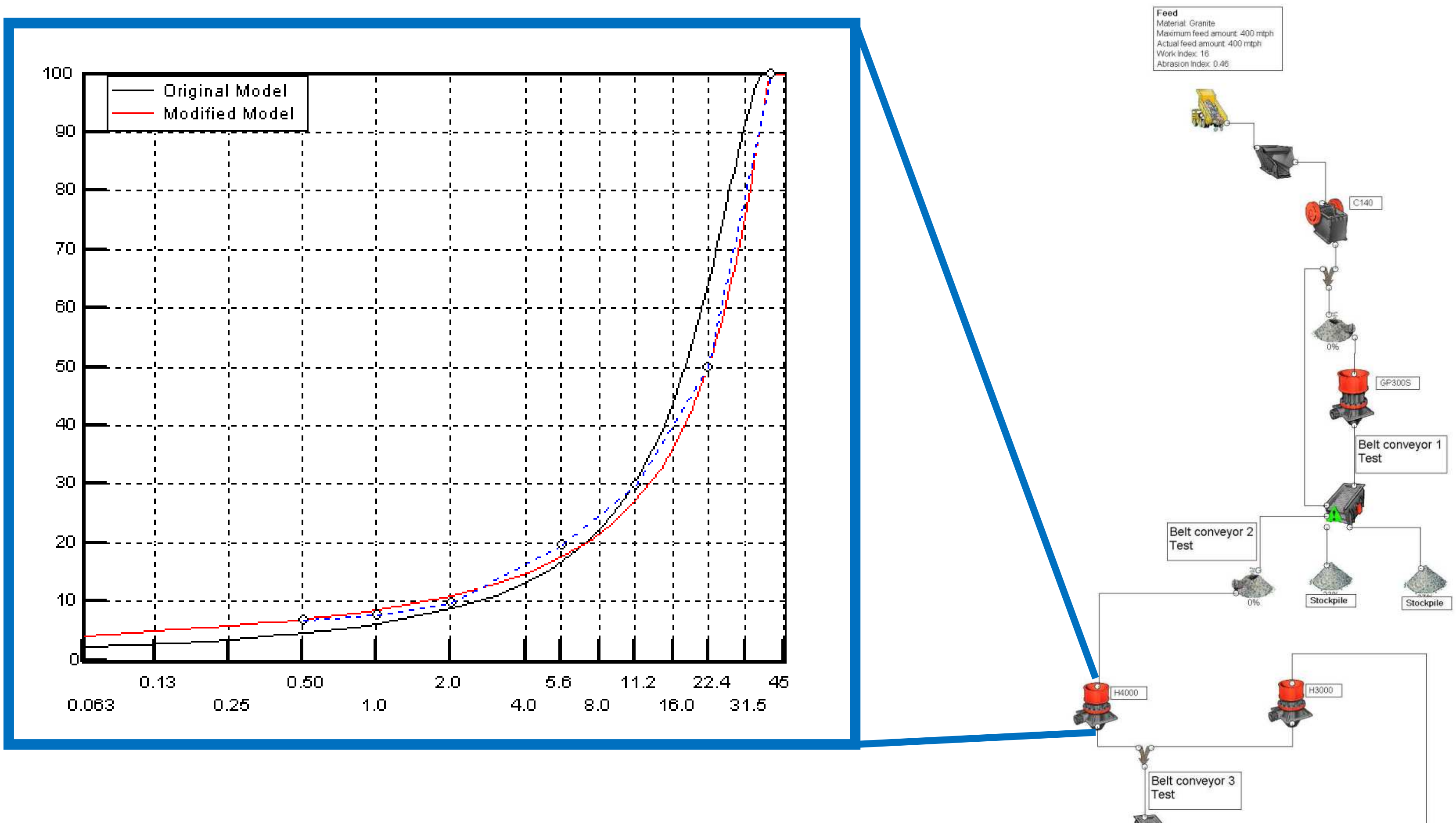
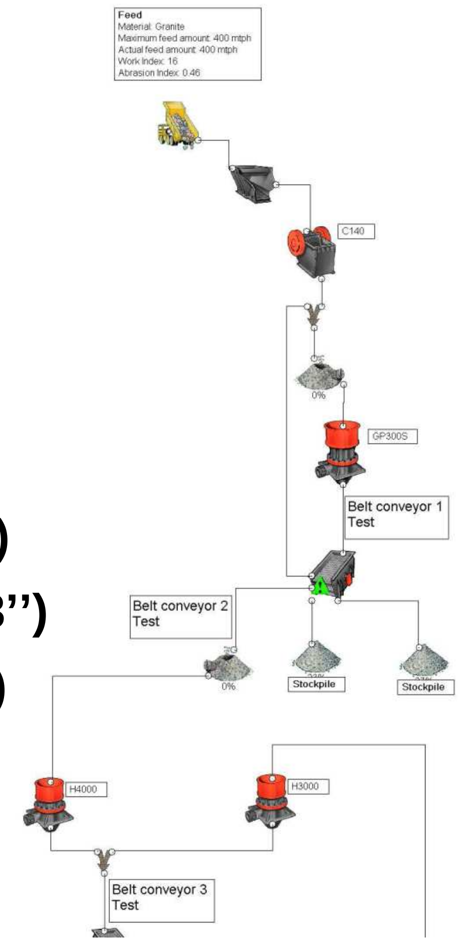
Crushing plant optimization using TCO Model Calibration



Crushing plant optimization using TCO
Running the TCO optimization module

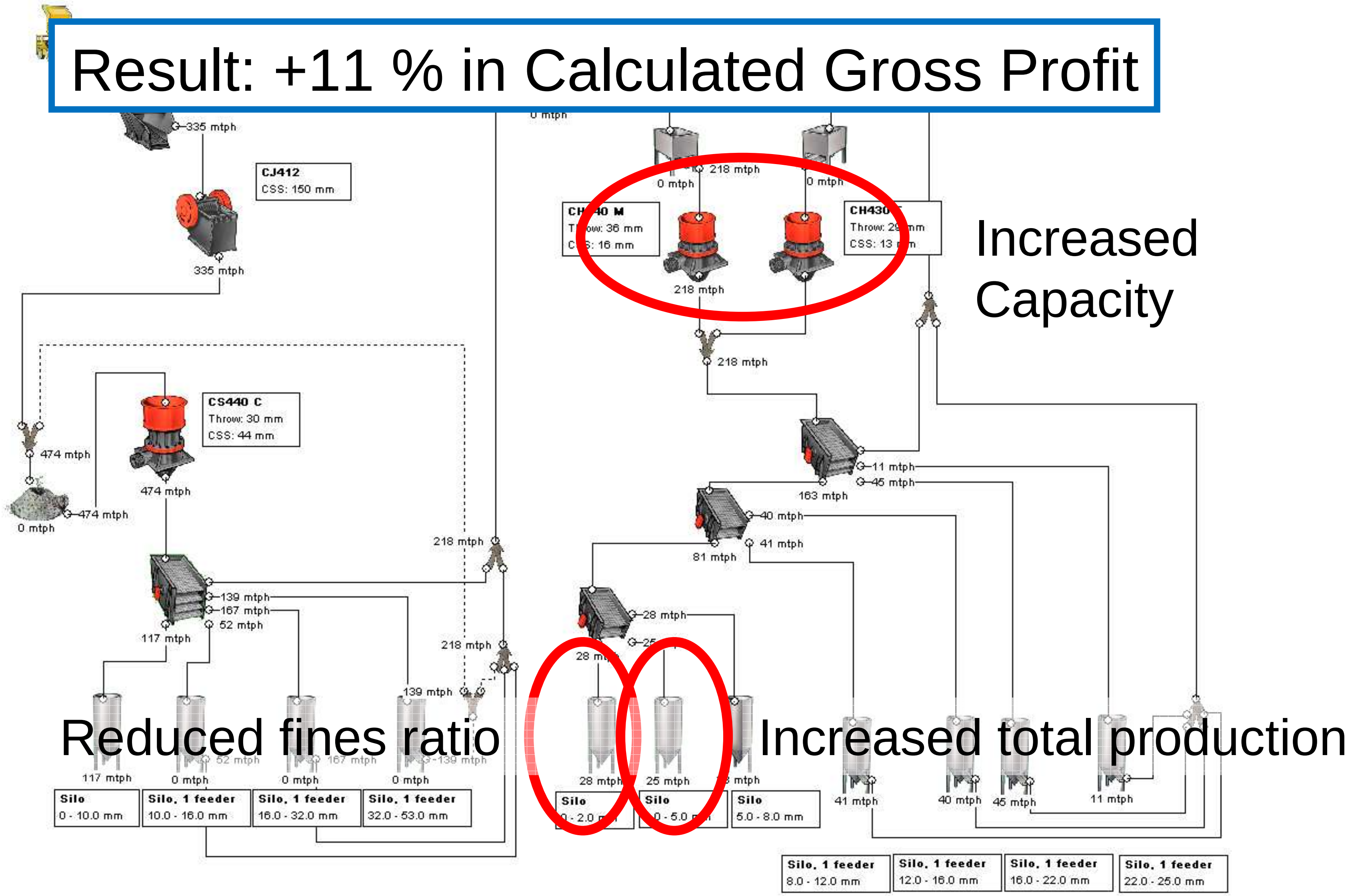
The computer tool automatically finds the best solution using an optimization algorithm

The solution that yields the best profit:

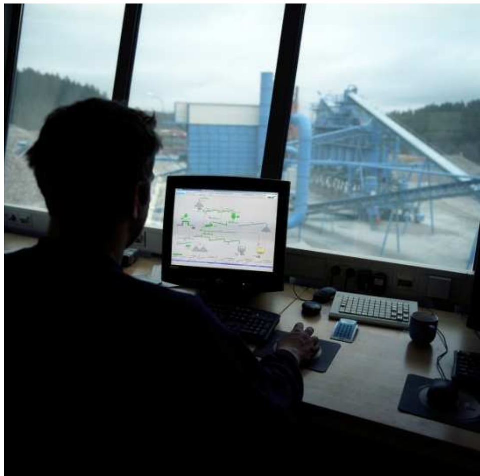


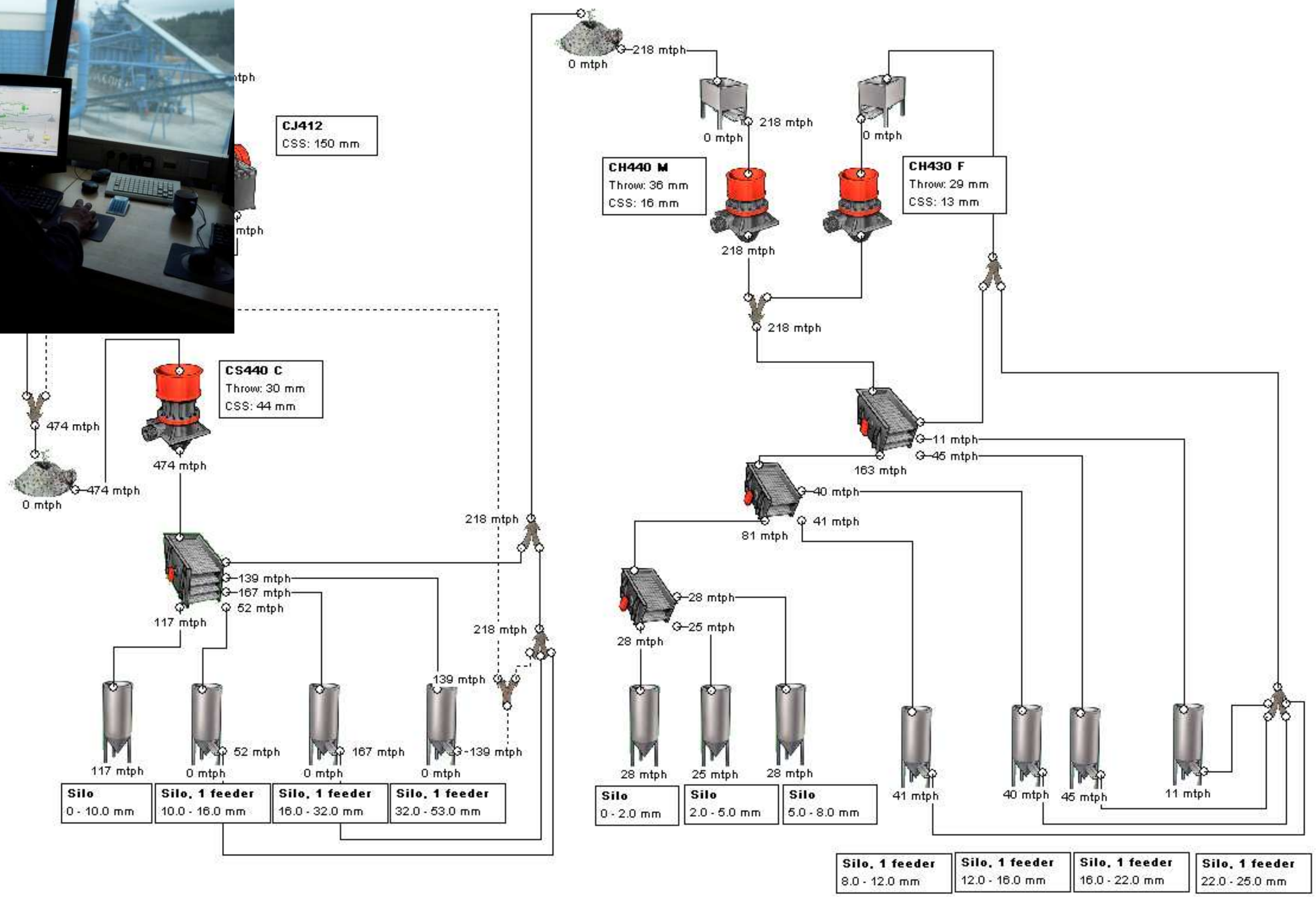
- **Secondary crusher – CSS 50 mm (44), 1.96'' (1.73'')**
- **Tertiary crusher – CSS 20 mm (16) 0.78'' (0.63'')**
- **Quaternary crusher – CSS 14 mm (13) 0.55'' (0.51'')**

Crushing plant optimization using TCO Results



Crushing plant optimization using TCO
How can it be done?





Crushing plant optimization using TCO
Conclusion

- Optimization must be a combination of technical and economic analysis
- Computer optimization can improve productivity
- Model calibration increases accuracy
- Minimizing cost does not necessarily maximize profit
- Combined performance of different machines should be considered. Solves the trade-off between capacity and reduction

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