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Considerations about the Return on Investment (ROI) for Online Analyzers in the Polysilicon Production

PVSEC

PV Production Forum

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Outline

1. Process Analyzers - Definition & Types
2. Process Optimization
3. Applications in Polysilicon Manufacturing
4. Influencing Factors
5. Calculation of Gain and ROI
6. Conclusion

Analytical techniques used in polysilicon production

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Process analyzers - What for ?

Perform a quantitative analysis of the chemical composition of certain process streams.

Usually, the process samples are either in a liquid or in a gaseous state.

Some analyzers work in an in-situ mode, others in an extractive mode.

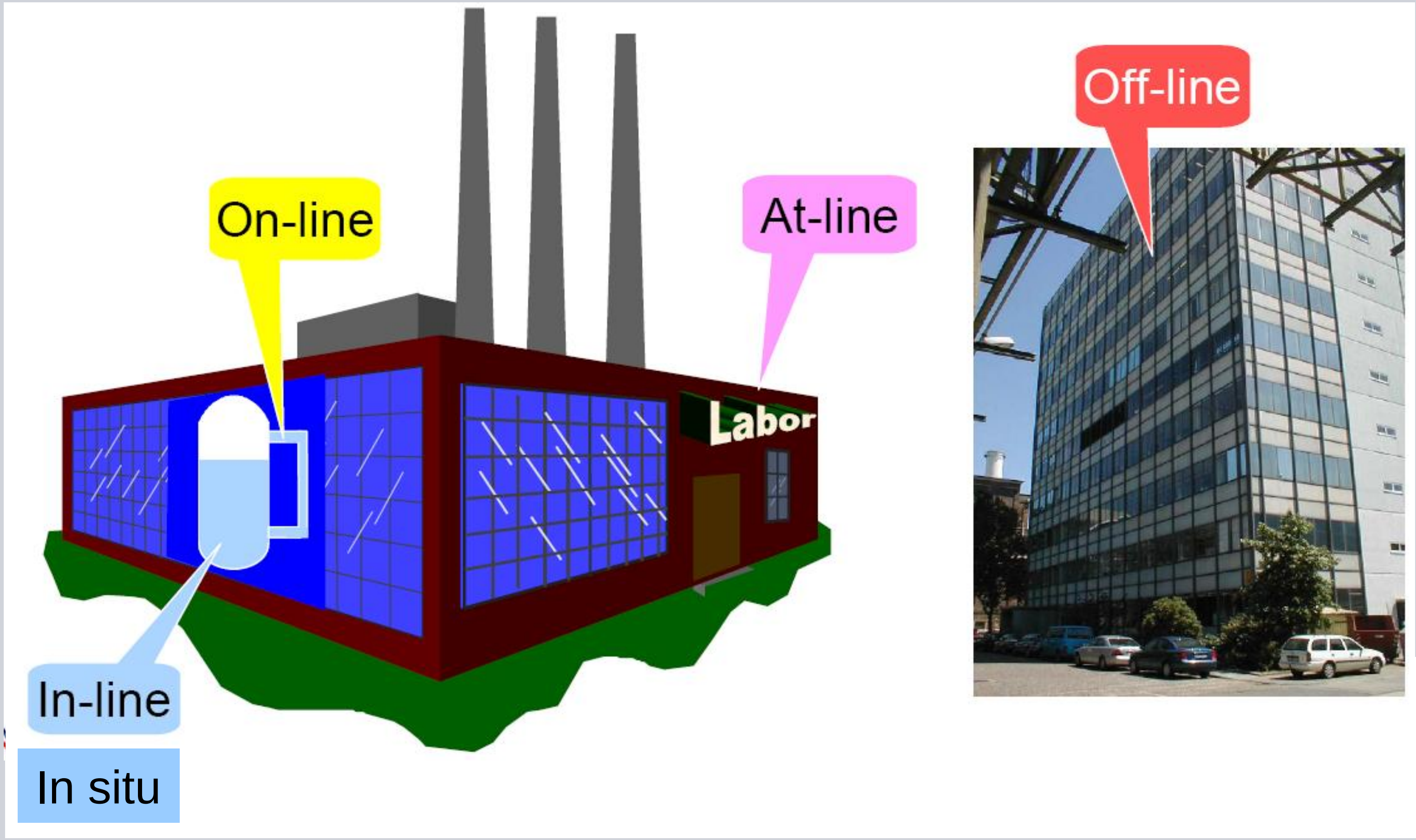
- Moisture analyzer
- Conductivity analyzers (for waste water)
- Simple gas analyzers (e.g. for O2, H2 or TOC)
- Gas chromatographs (GC)
- Laser spectrometers (NIR)
- Infrared spectrometers (FT-IR)
- Raman spectrometers
- Mass spectrometers (MS, ICP-MS)

Source: Groton Biosystems, Boxborough, MA, USA

Online analysers provide high data quantity, but are considerably more expensive

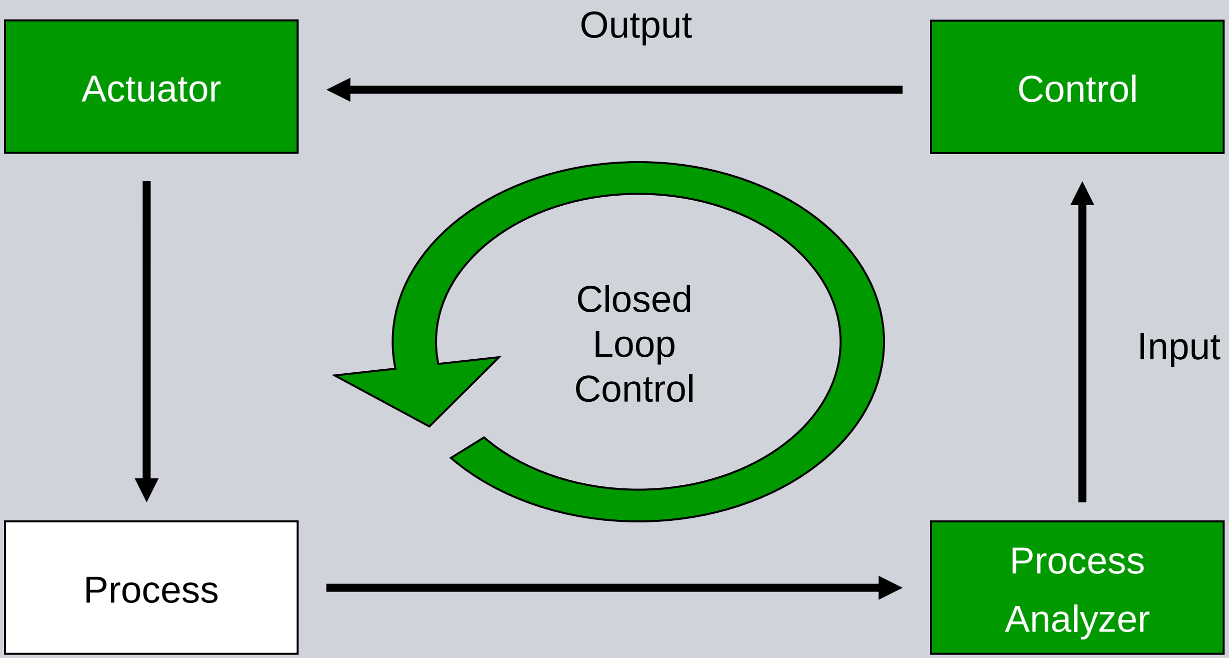
Price range: 10.000 - 400.000 USD

Operation modes of analyzers



Source: BASF, Dresden, 2006,
European User Meeting Siemens

Process automation



Preconditions :

- Automated
- Fast
- Continuous
- Reliable
- Accurate

Potential for process optimization

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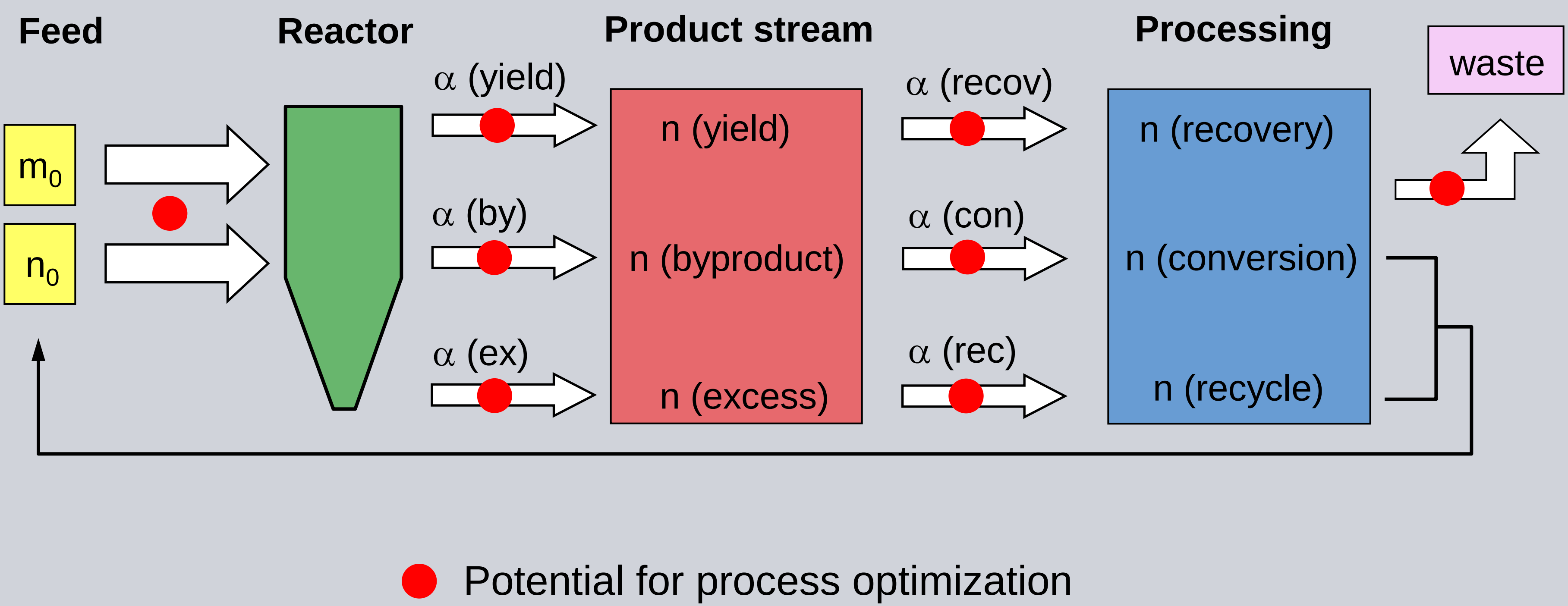
Material balance : general scheme



α = conversion rates

Improved Siemens process: applications for process analyzers

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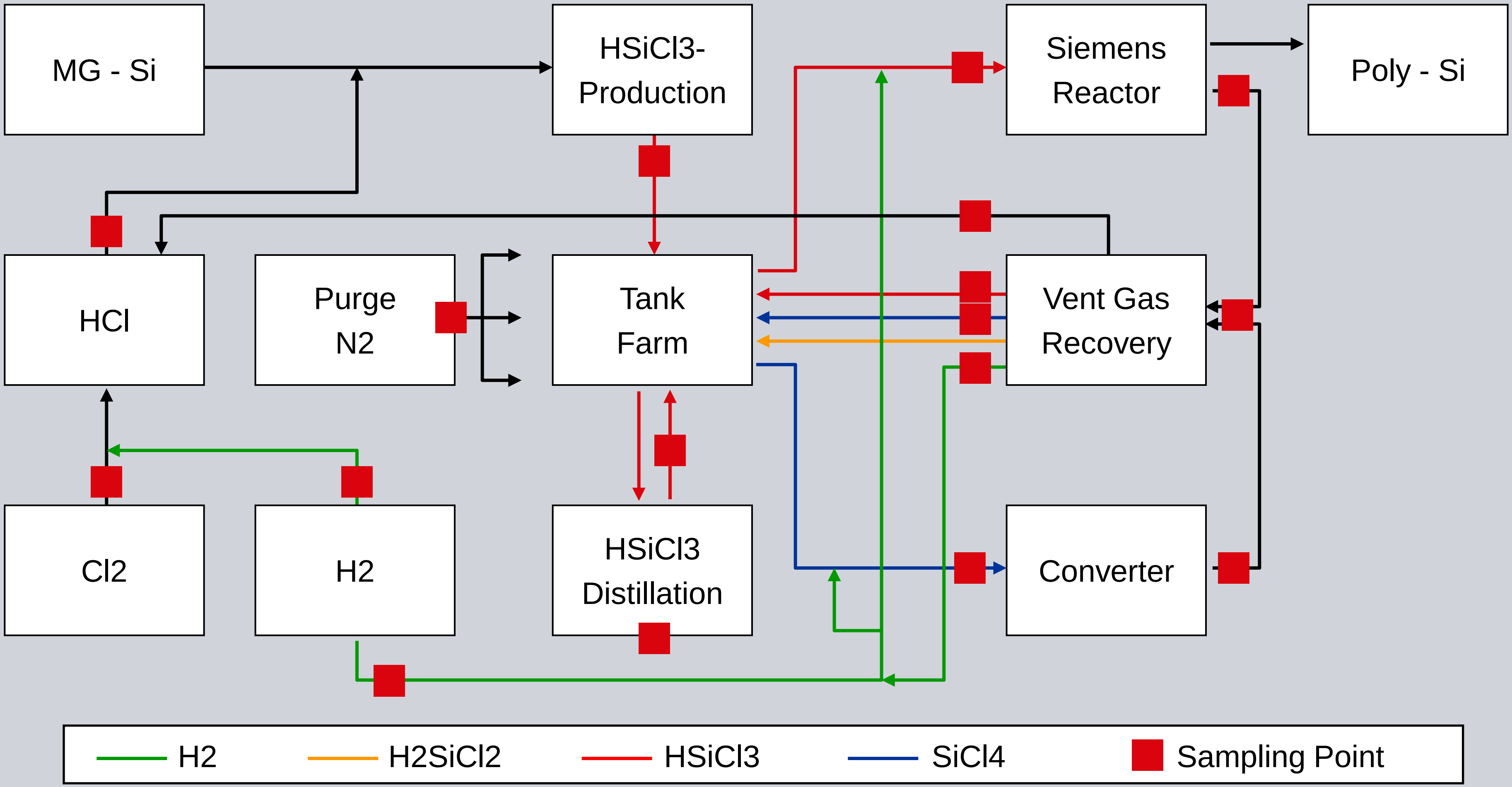

CVD reactor:
Impact of change in process parameters

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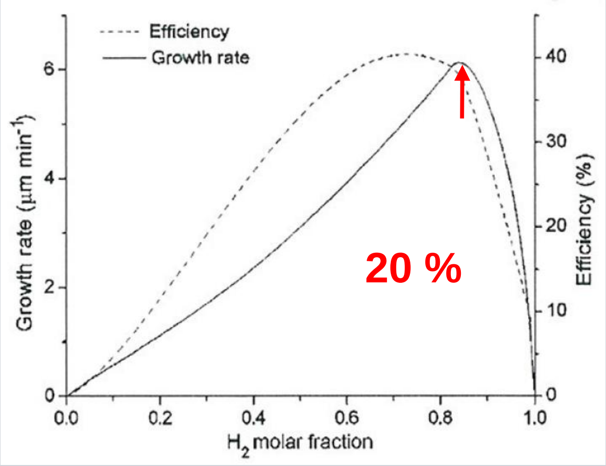
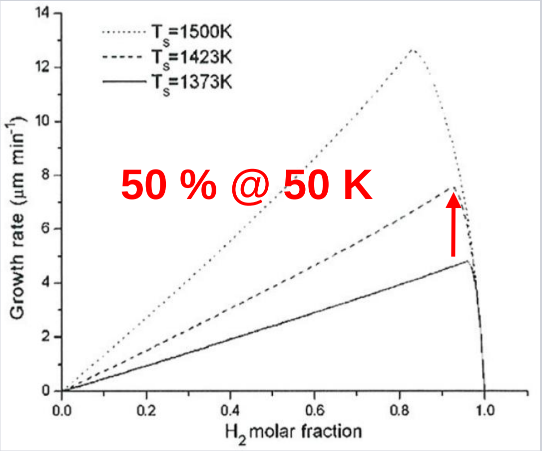
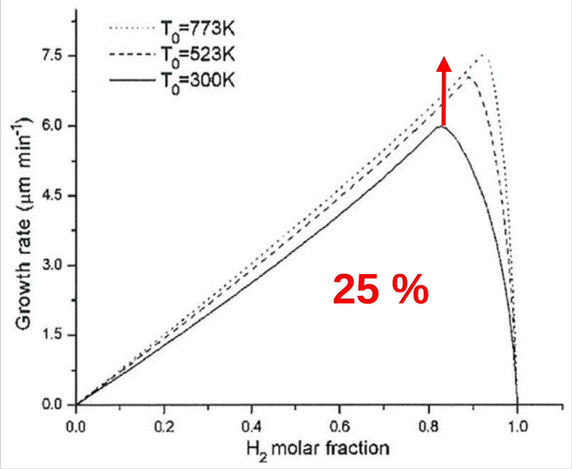


Feed gas composition

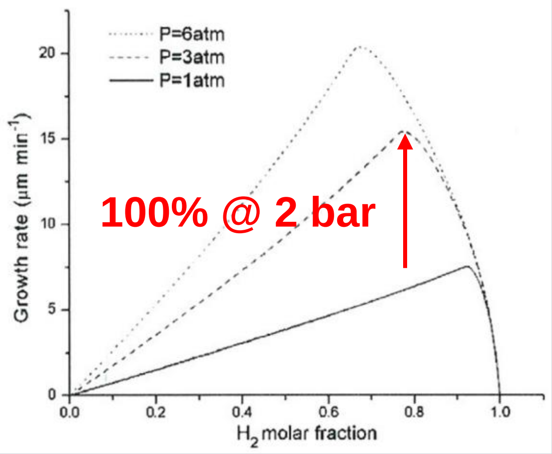
Rod surface temperature





Feed gas temperature

Reactor pressure



Source: G. del Coso et al., *Journal of Electrochemical Society*, 155 (2008) D485 - D491

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Factors impacting ROI

Analytical system (technique, layout, price) Performance of analytical system (cycle time, accuracy, uptime)	**Analyzer**
Type of chemical process: manufacturing technology and individual process step Sampling point	**Application**
Production cost Local purchase prices of feedstock material Market price of final product Costs for waste removal and for recycling of byproducts Costs for modification of process conditions (temperature, pressure, flow etc.)	**Costs**
Scale of production	**Quantity**
Current degree of optimization (relative to real optimum*) Achievable improvement (optimization rate) Stability and accuracy of process control (before & after) Automation concept (close loop control) Process knowledge of the plant operator Current ratio of feed components (oversupply)	**Process control**

* based on thermodynamics and process conditions, not based on licensor specifications (design data)

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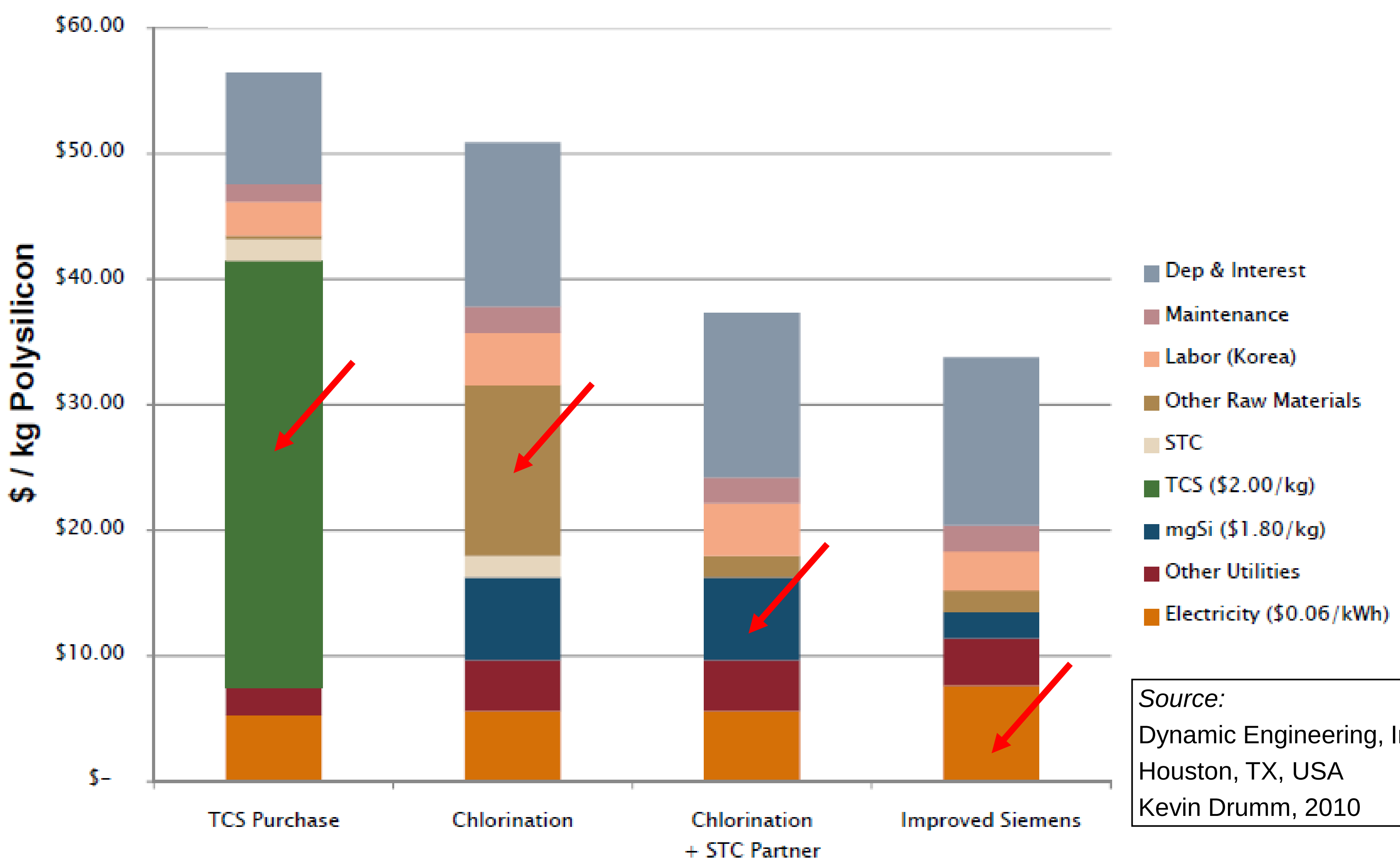
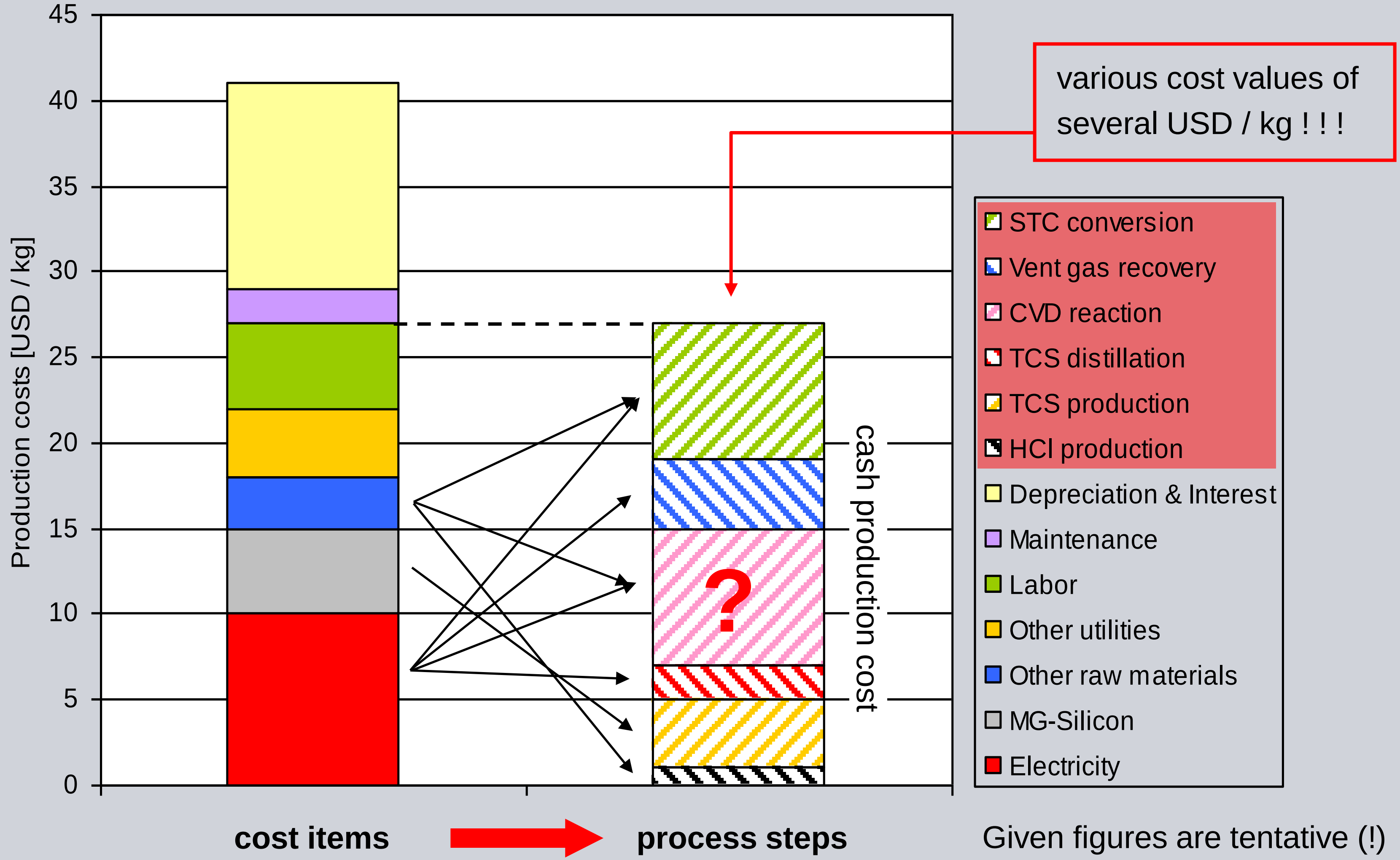
Polysilicon production cost breakdown: Example



Source:
Dynamic Engineering, Inc.
Houston, TX, USA
Kevin Drumm, 2010

Production cost: Breakdown into process steps



Given figures are tentative (!)

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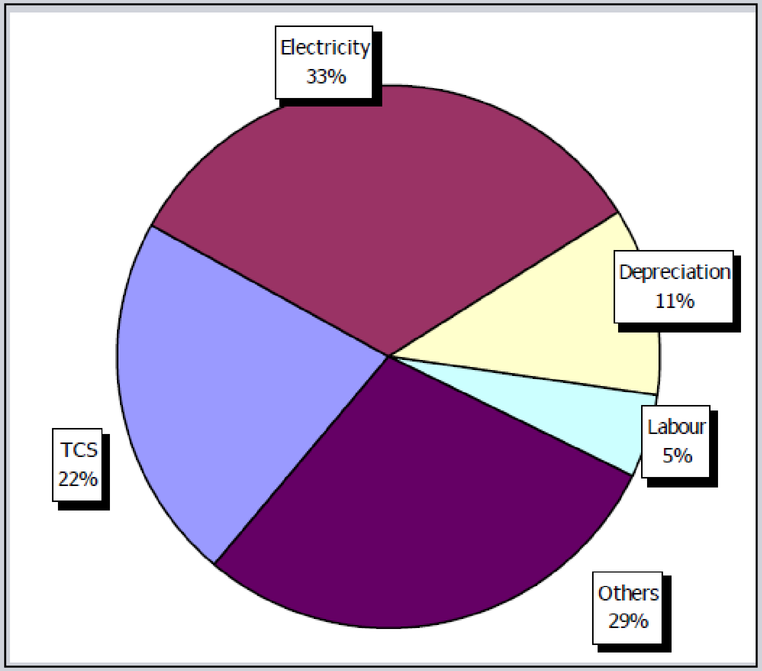
Gain by Process Optimization

$$G_P = P \times V \times O$$

$$G_C = C \times V \times O$$

$$ROI = (I / G) \times 12 = \frac{12 \times I}{C \times V \times O}$$



Source: GCL company data & Kingsway Research, Hong Kong, China, 2009

G	Gain (USD / year)
P	Production of polysilicon (kg / year)
C	Capacity of polysilicon (kg / year)
V	Cost value (USD / kg of polysilicon)
O	Optimization rate (% of current figure)
ROI	Return on investment (months)
I	Capital investment for the analytical system (USD)

Accumulated gain and ROI for various optimizations rates

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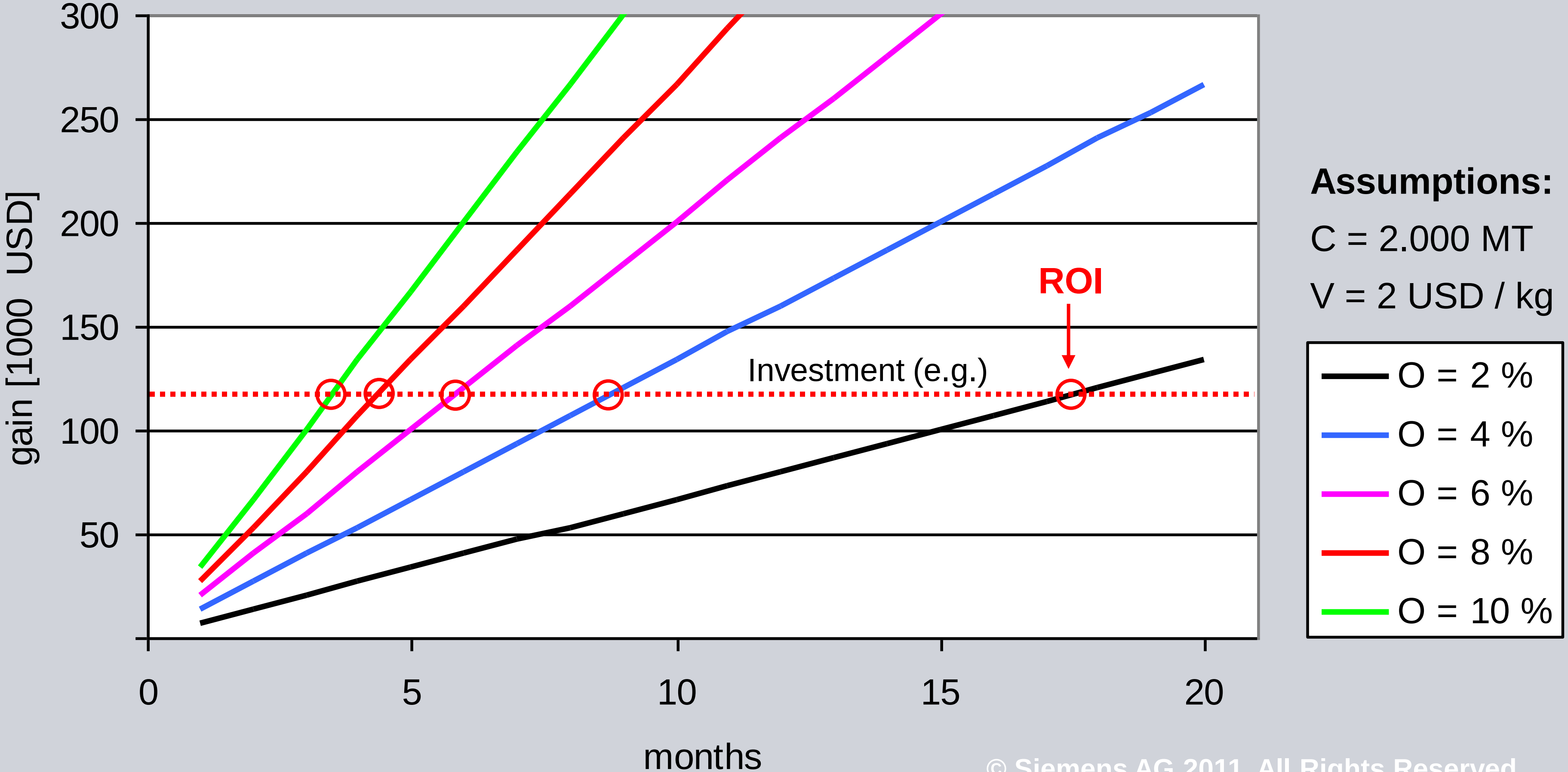
Formula: G = C x V x O



Assumptions:

C = 2.000 MT

V = 2 USD / kg

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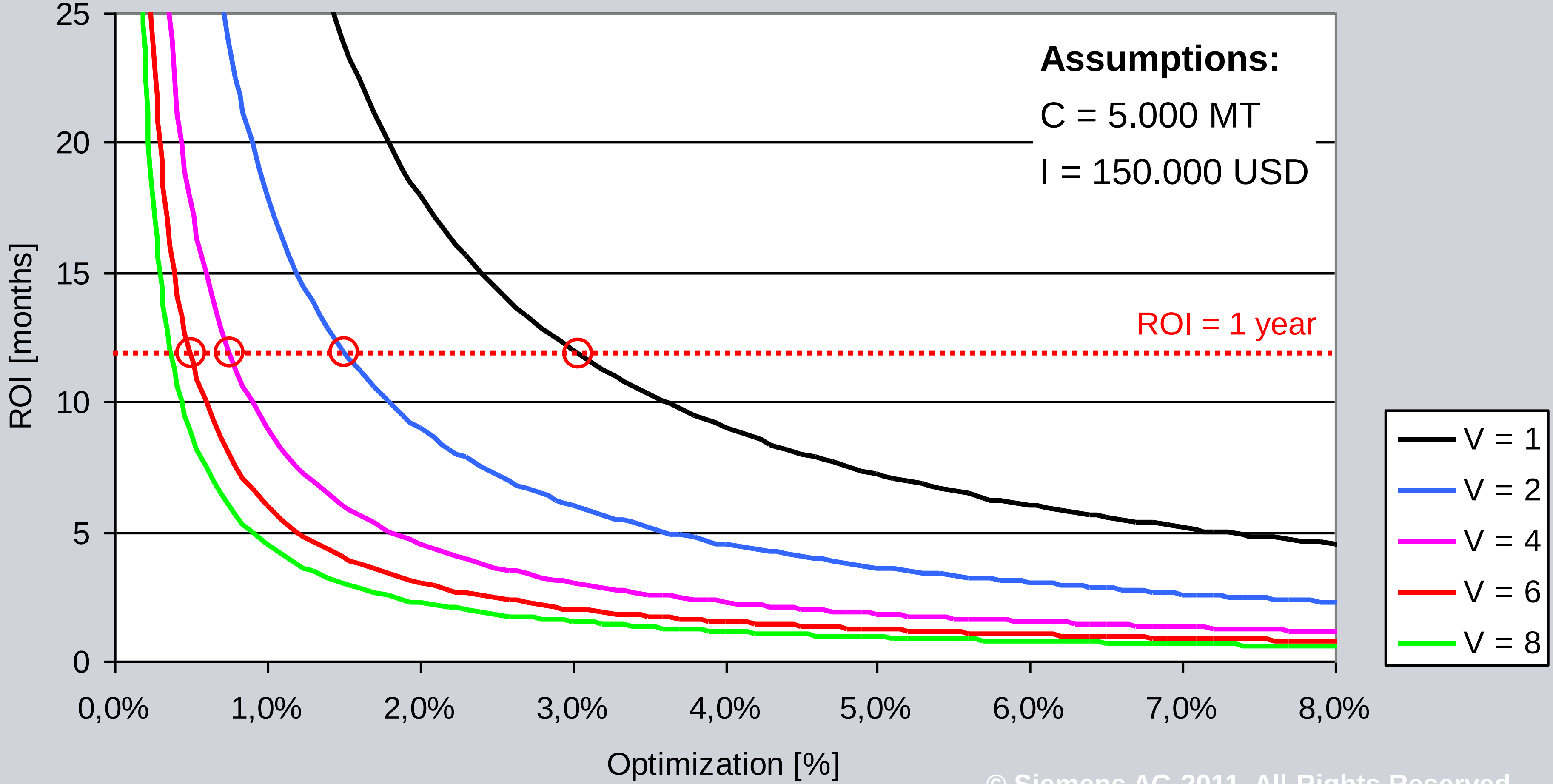
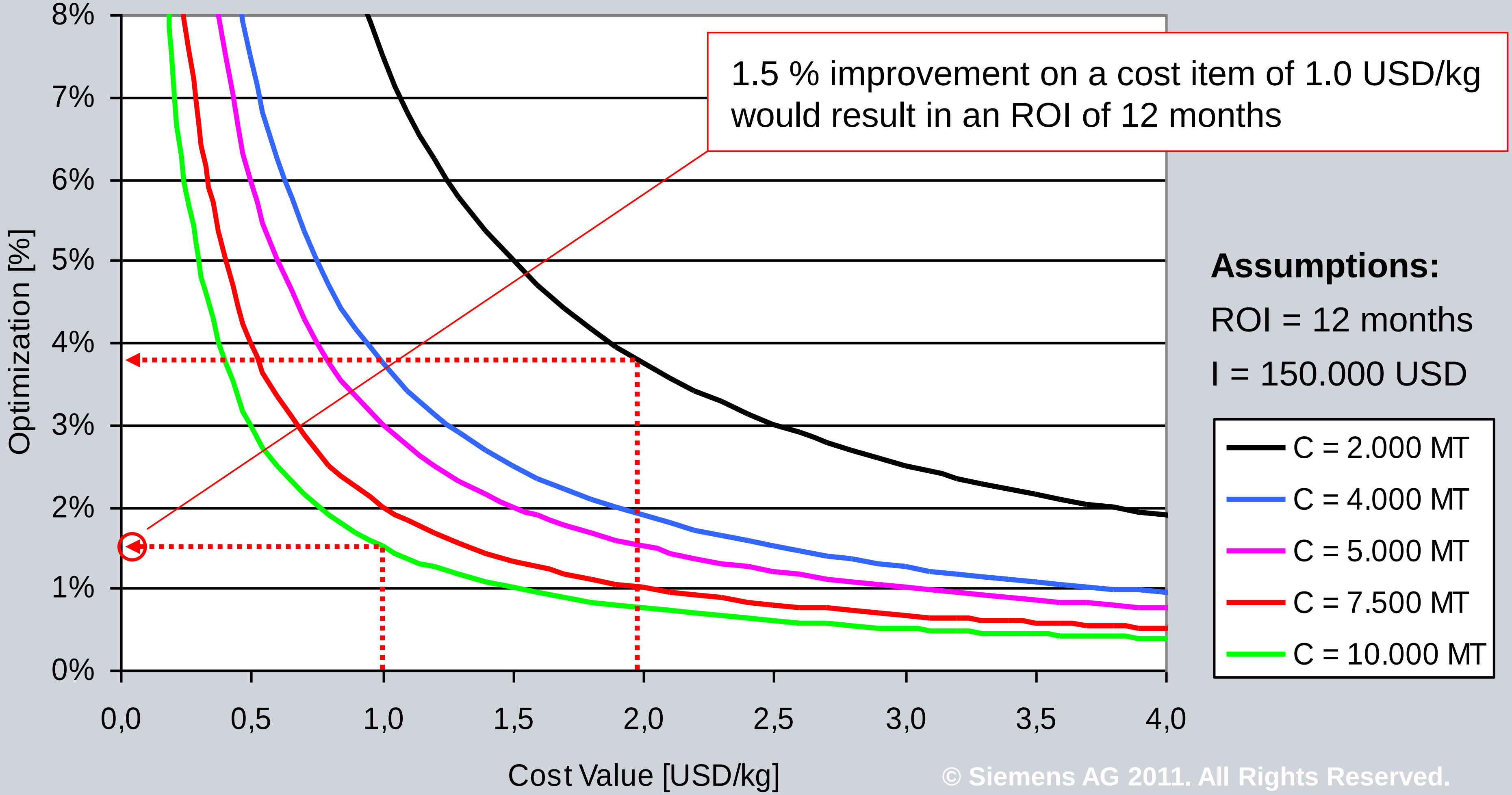
ROI for various cost values

$$ROI = \frac{12 \times I}{C \times V \times O}$$



Optimization rates for various plant capacities

$$O = \frac{12 \times I}{C \times V \times ROI}$$



Assumptions:

ROI = 12 months

I = 150.000 USD

Conclusion

- applied correctly and efficiently, process analyzers bear great potential
  to squeeze production costs
- rule of thumb: typically ROIs can be expected within a range of 6 up to 18 months
- the calculated ROI represents the respective potential, i.e. the lower limit
- how far this potential is going to be exploited, will depend on the operator
- two factors are decisive / mandatory:
  a) the process knowledge of the operator
  b) the systematic implementation of the analytical results into a concept of process automation
- the use of process analyzers may be profitable
  a) for small scale plants due to high production costs (USD/kg polysilicon) - parameter V is large
  b) for large scale plants due to high material throughput - parameter C is large
- in the end it's a question of ambition: is the operator aiming at cost leadership - or not ?

Thank you for your attention!

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