Site-wide energy management

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  - Complexity of the site
  - Network streams
  - Why is it complicated?
- Desired Application: Possible Technical Solution
  - General
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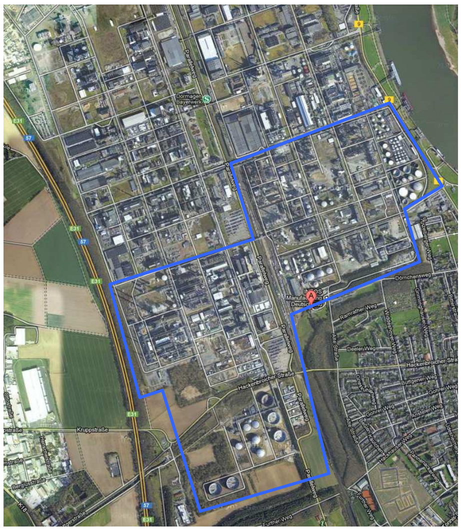
Motivation or „Why is it complicated?"

- More than 20 plants
- Connected to networks:
  - Electricity
  - Fuel Gas
  - Steam (30, 15, 5 bar)
  - Cooling Water
  - Boiler Water
  - Condensate
  - Compressed Air
  - Nitrogen

  - Raw materials
  - Intermediates
  - Products
- No plant is connected to every network



1 km

© Google maps

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Motivation or „Why is it complicated?"

- Power plant is the local steam producer
  - Many plants produce excess steam
  - Other plants require steam
- Power plant is also a waste burning facility
  - A large number of constraints
- Balancing the Power plant as steam and power generator and sink for offgases is necessary
  - significant benefit of optimisation expected
- Networks of
  different gases and steam headers need to be balanced
  - significant benefit of optimisation expected
- A large number of discrete degrees of freedom
- Discrete and continuous variables

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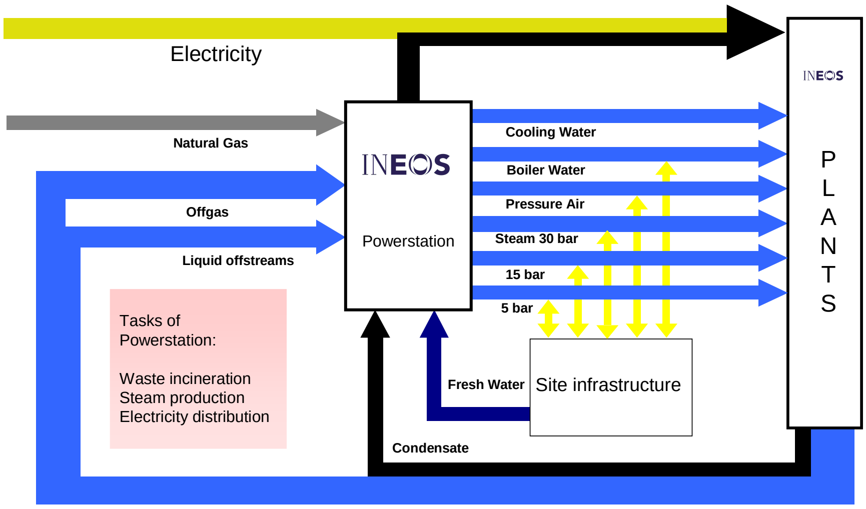
Cologne Site Energy Network



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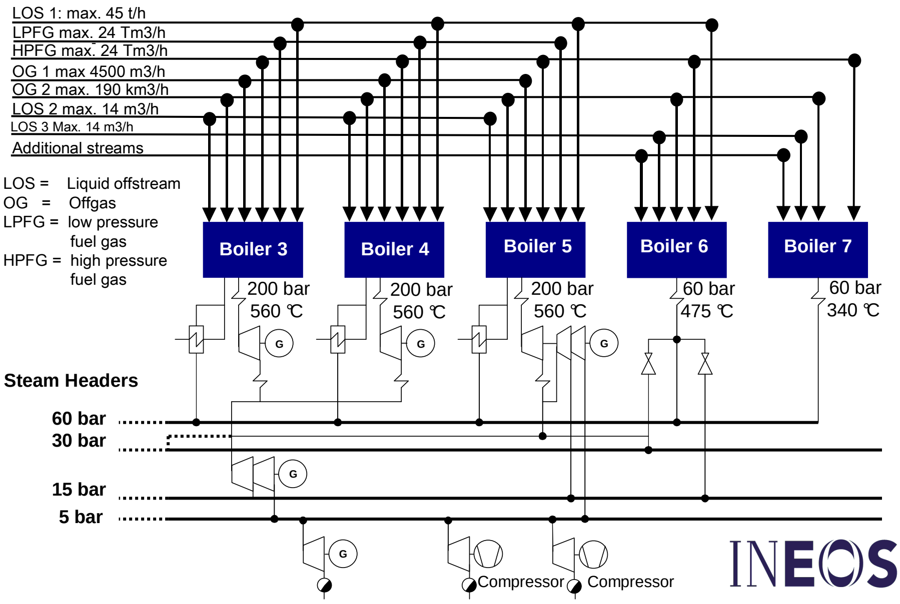
Example: Steam and Power Generation



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Application

- Networks requires planning in accordance with production:
  - Long term planning – Disposition
  - Short term planning – Scenario based optimisation
  - Online optimisation

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Desired Application

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Modelling details

- Use of one model for all applications
- Setup as a real optimisation problem that natively considers technical and economical constraints
- Flexible user interface and reporting system
- Will include:
  - Distribution of the different fuels to the different boilers
  - Overall efficiency of each of the boilers
  - Enthalpie of the different steams (to find overall optimimum of energy consumption/production)
  - Plant production scenarios on how to optimise the site
- **Size of model:**
  Example Boiler 3 described by appr. 360 equations

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Application Example

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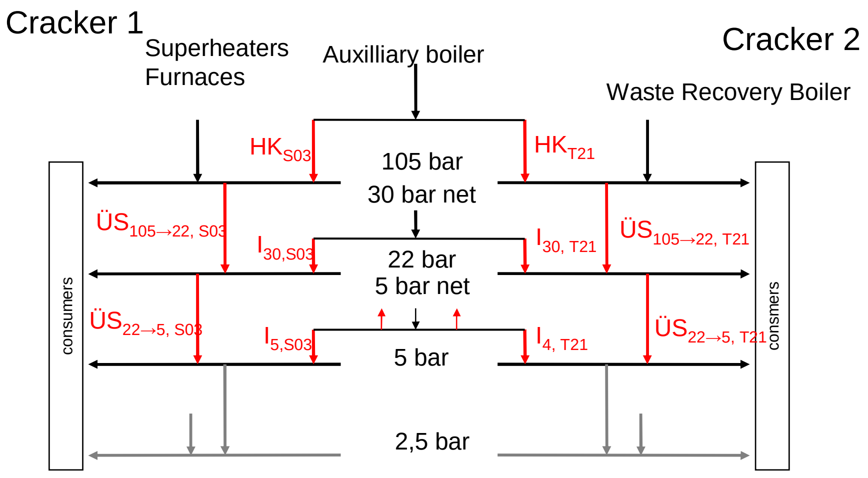
Optimisation of Cracker Steam Headers



Variable steam streams (degrees of freedom)

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Optimisation: Cost function

- Optimisation minimises the import cost of steam on different header levels

$$\min\left(HK_{S03}^{opt} + HK_{T21}^{opt}\right)\cdot p_{105} + \ldots$$
$$\ldots + \left(I30_{S03}^{opt} + I30_{T21}^{opt}\right)\cdot p_{30} + \left(I5_{S03}^{opt} + I5_{T21}^{opt}\right)\cdot p_{5}$$

- Steam price on different header levels
  - From current energy costs
  - Determined within the routinely performed optimisation of the crackers

- Price of HP-steam by auxilliary boiler equals production costs

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Optimisation: Mass Balance model

- Mass balances on different header levels
- Consumers considered to be fixed
  $\Rightarrow$ automatically considered
- HR-boiler (T21), superheaters and furnaces fixed
  $\Rightarrow$ automatically considered

Example 105-bar-system S03:

$$HK^{(IST)} + \cancel{P_{21/22}^{(IST)}} + \cancel{P_{65/66}^{(IST)}} + \cancel{P_{EÜ}^{(IST)}} - \cancel{V_{RGM}^{(IST)}} - ÜS_{105-22}^{(IST)} =$$
$$HK^{(OPT)} + \cancel{P_{21/22}^{(IST)}} + \cancel{P_{65/66}^{(IST)}} + \cancel{P_{EÜ}^{(IST)}} - \cancel{V_{RGM}^{(IST)}} - ÜS_{105-22}^{(OPT)}$$
$$\Rightarrow HK^{(IST)} - ÜS_{105-22}^{(IST)} = HK^{(OPT)} - ÜS_{105-22}^{(OPT)}$$
$$\Rightarrow HK^{(IST)} - ÜS_{105-22}^{(IST)} - HK^{(OPT)} + ÜS_{105-22}^{(OPT)} = 0$$

- 22 bar and 5 bar described similarly
- 22 bar and 30 bar considered as one system

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Properties of the developed approach

- **Minimal number of online measurements:**
  Consumers and fixed producers not considered
  $\Rightarrow$ Minimimal number of possible measurement errors
- Technical **constraints** can be adjusted easily
- Balances of enthalpy are calculated separately:
  Problem remains **linear**
- **Easy to extend:**
  e.g. considering additional degrees of freedom, …

- **Methodology** as can be applied to other steam networks, e.g. power station

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Optimisation: Numerical solution

- General formulation:

$$\min_{\mathbf{x}} \Phi = \mathbf{f}^T \mathbf{x}$$

u.B.v.

$$\mathbf{A}_{eq}\mathbf{x} = \mathbf{b}_{eq}$$

$$\mathbf{A}\mathbf{x} \leq \mathbf{b}$$

$$\mathbf{x}_{min} \leq \mathbf{x} \leq \mathbf{x}_{max}$$

- Problem is set up as Linear Program (LP)
- Effective solvers available
- MATLAB used as numerical platform

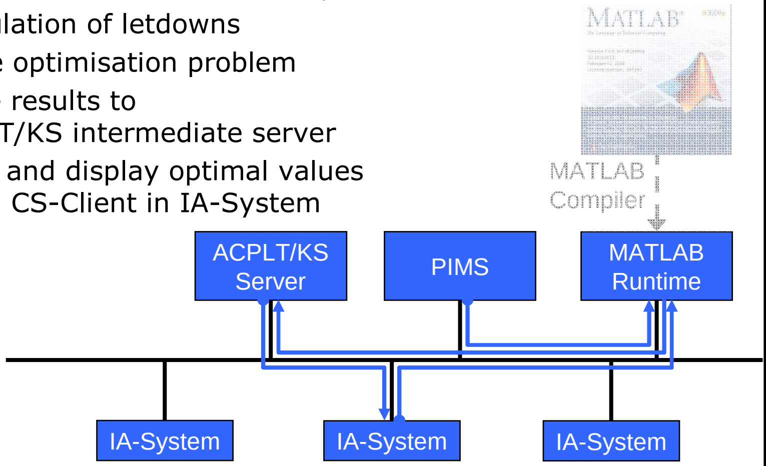
Operation as Operator Advisory

- Two identical DCS screens in both crackers
- Informationen about status:
  - Solution found?
  - What is the benefit?

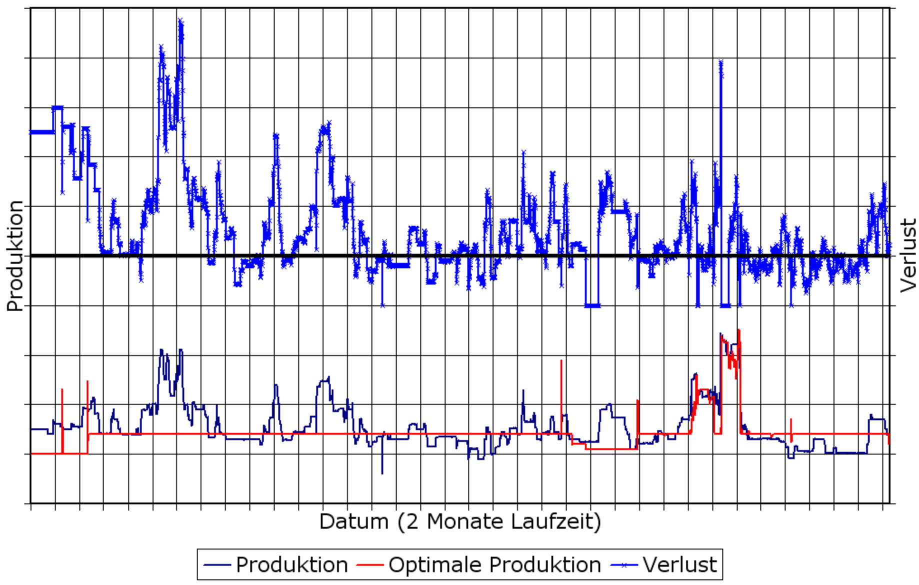
- Operation only possible in one cracker
  (to avoid inconsistent changes of constraints)
- Main technical or operational constraints can be adjusted:
  - Production of boiler Min and Max
  - 30 Bar Import Min and Max
  - 5 Bar Import Min and Max
  - 5 Bar Export Min and Max

Technical realisation: MATLAB and ACPLT/KS

- Solution every 2-minutes with MATLAB (runtime):
  1. Read and filter data from PIMS by ACPLT/KS
  2. Read constraints from DCS by ACPLT/KS
  3. Calculation of letdowns
  4. Solve optimisation problem
  5. Write results to ACPLT/KS intermediate server
  6. Read and display optimal values using CS-Client in IA-System



Long Term Results



Why do we need advanced solutions and more research?

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Expected Results

- Online advisory for operators on how to operate the plants
- Short term planning on steam and power generation including production load balancing for optimal energy usage
- Long term planning on steam and power generation and optimal scheduling of shutdowns

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Challenges – Tools and Research Required

- **These are the points where we need help**
- Optimal choice of unit operation
- Daily and long term production balancing
- Alternative operation strategies
- Solution on different time scales:
  - online load/demand balancing
  - hourly, daily, and monthly scale
- Compensate day and night changes, average planned production using load changes for optimal operation
- Optimal long term planning
- Closed loop operation
- Documentation

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We need Methods and Tools

- We think only the methods of Advanced Modelling, Advanced Control and Advanced Optimisation can solve this problem
- We cannot solve it alone – Coordinated research is needed
- Significant benefits are expected both environmental and monetary

- Some solutions can be bought, some solutions exist, most solutions need to be developed
- ACCESS would have helped us significantly!

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Questions

Please!