



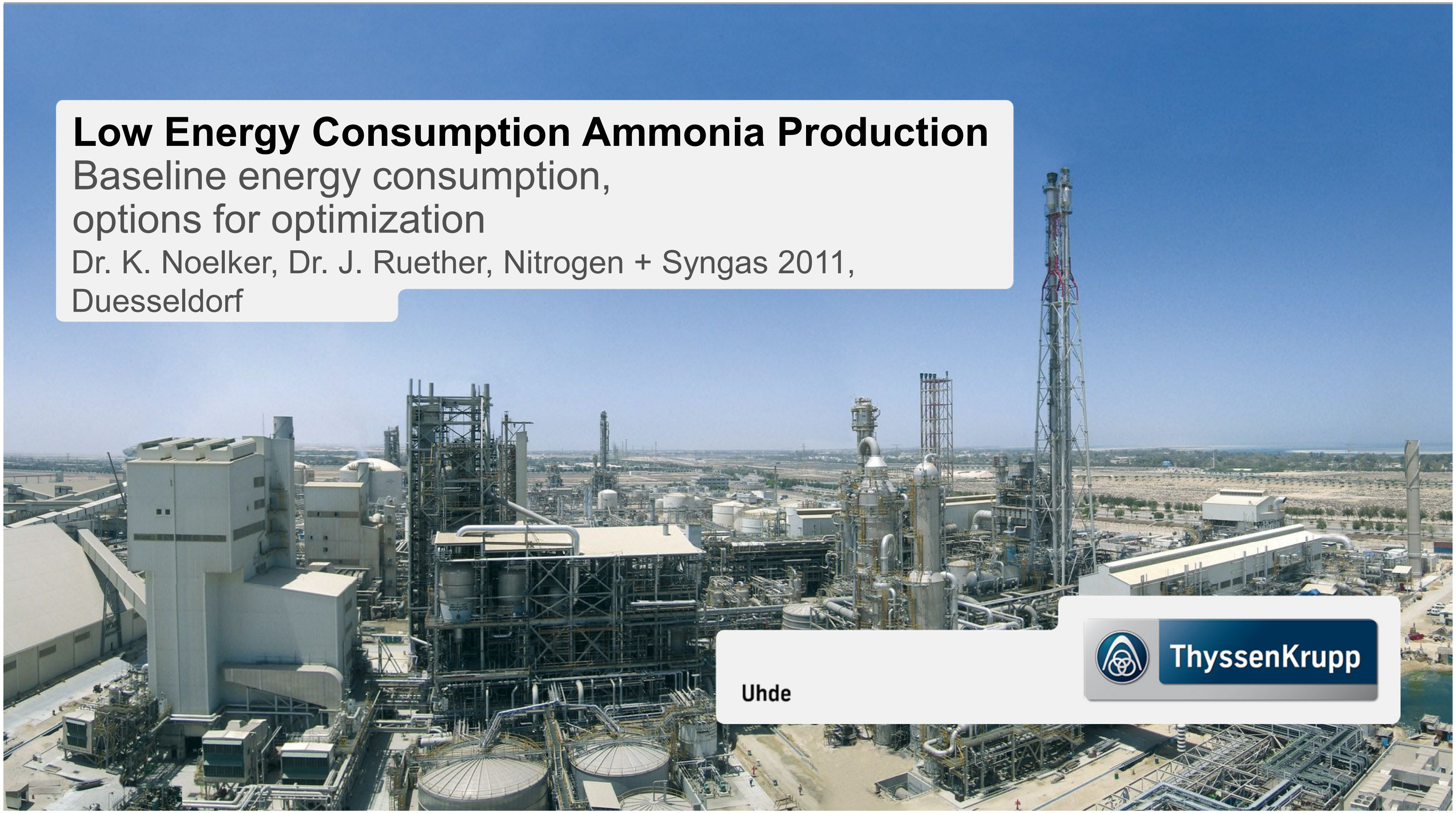

Low Energy Consumption Ammonia Production

Baseline energy consumption, options for optimization

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Overview

- Introduction
  - Why think about energy consumption?
  - History of energy consumption figures
- Minimum realistic energy consumption of conventional processes
- Examples for energy saving measures
  - Minimization of heat release to the environment
  - Extended physical desorption for solvent regeneration in CO_2 removal
  - High efficiency energy conversion
  - Use of high efficiency turbo-machinery
  - Reduced pressure drop
- Comparison of consumption figures
- Summary

Introduction
Why think about energy consumption?

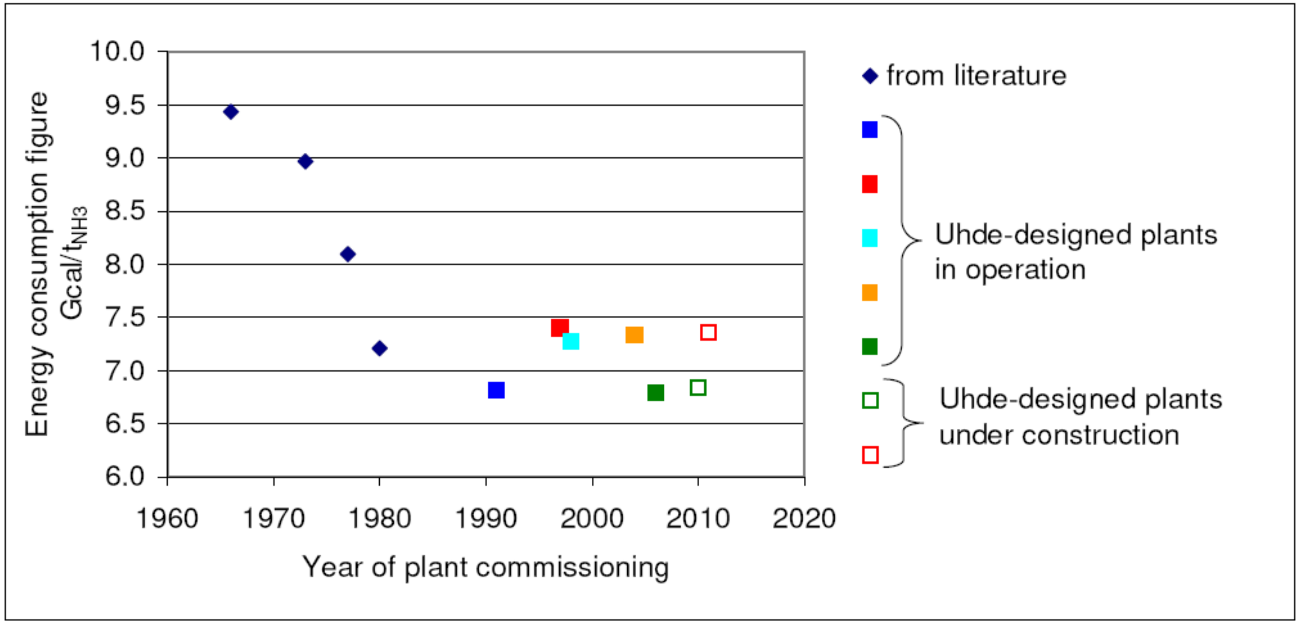
- Economical point of view:
  Natural gas is not a cheap by-product of oil production any more – prices are increasing all over the world.
  - Many fertilizer plants already lost the ability to produce competitively due to rising energy cost
  - Value of energy savings increases with gas price
  - Example: energy saving of: **0.1 Gcal/t_{NH3}**
    corresponds to net present value: **8.7 million USD**

Conditions:	plant size: 2,000 mtpd	gas price: 3 USD / MMBTU
	time horizon: 15 years	interest rate: 5%

- Ecological point of view:
  A considerable portion of the ammonia-production related CO_2 emission may at first be fixed in urea, but it will be released to the atmosphere upon urea decomposition

Introduction
History of energy consumption

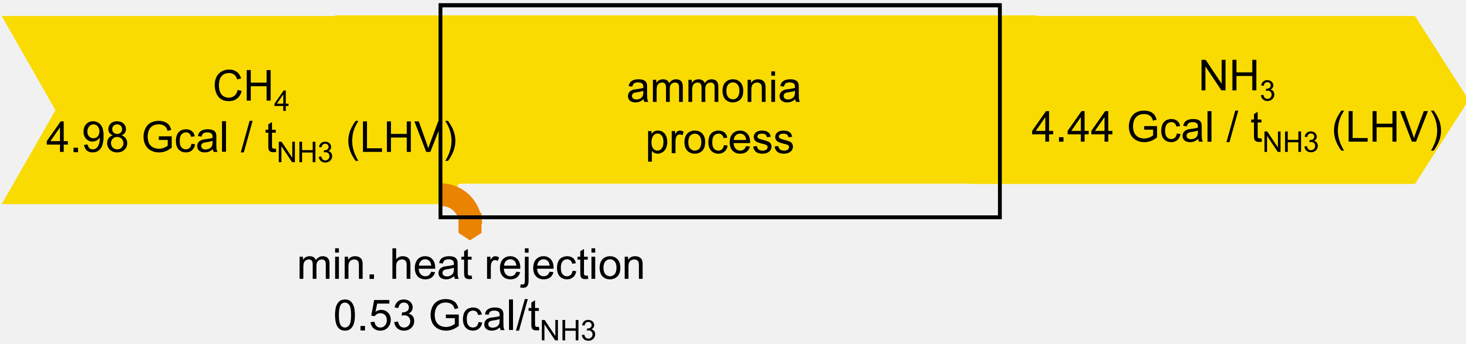
- Energy consumption was significantly reduced in the 1970s
- No obvious trend since about 1990, consumption figures ranging in between of 6.7 and 7.4 Gcal/t NH_3



- Stagnation due to low gas cost or for physical reasons?

Minimum realistic energy consumption
Chemical baseline and reason for heat rejection

- Input for NH_3 production from CH_4, air and steam: 4.98 Gcal/t_{NH3} (from reaction stoichiometry)
- Energy in ammonia product (expressed as LHV): 4.44 Gcal/t_{NH3}



- Higher heat rejection in the real process due to process requirements:
  - selected temperature and pressure levels
  - energy recovery by steam cycle: limited efficiency
  - dissipational effects (friction)
  - overstoichiometric process steam ... and other

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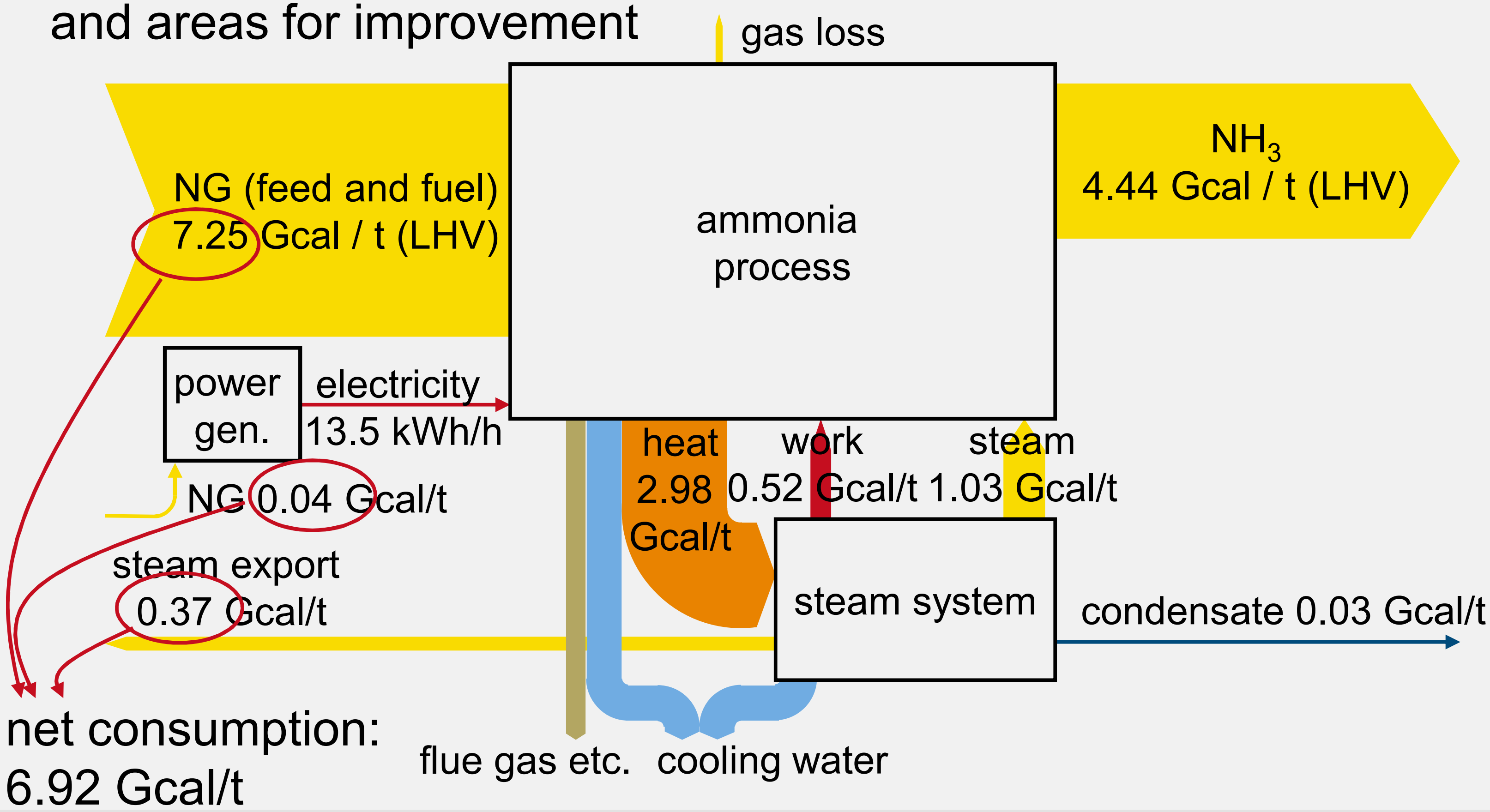
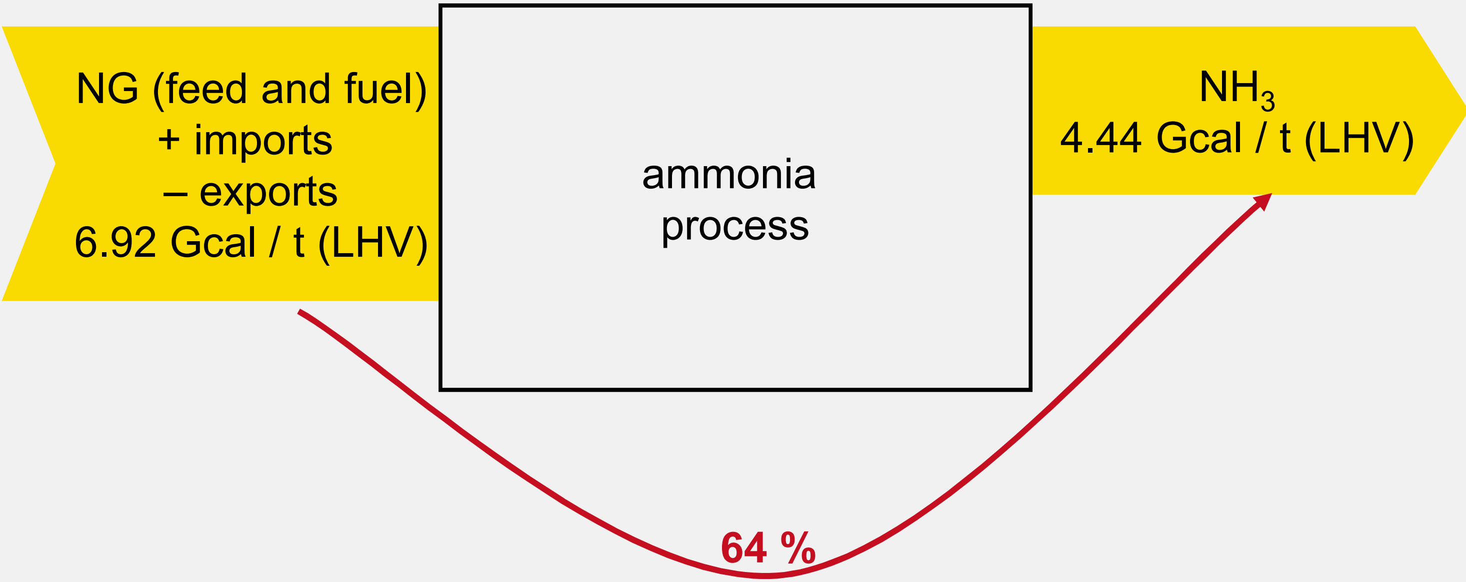
Minimum realistic energy consumption
Analysis of actual energy flows

- Energy flows of actual modern ammonia plant – showing loss streams and areas for improvement



Minimum realistic energy consumption
Analysis of actual energy flows

- Example from modern ammonia plant: 64 % of the energy consumption ends up in the product



Minimum realistic energy consumption

- Approaches for reducing the energy consumption:
  - Reduce heat release from process ⇒ lower energy input
  - Increase efficiency of steam system ⇒ more value from waste heat
- Practical limits:
  - Limitations for heat release from the process:
    - Loss to water coolers cannot be avoided because there is waste heat present at a low level not favourable for recovery
    - Reformer stack temperature preferred above 100 °C
  - Steam system: optimisation to 40 % efficiency assumed
- Result: baseline at approx. 6.5 Gcal per ton of ammonia
  - Lower consumption only with high efforts
  - Not identical to the economic optimum

Options for saving energy (1)
Minimised direct heat release to environment

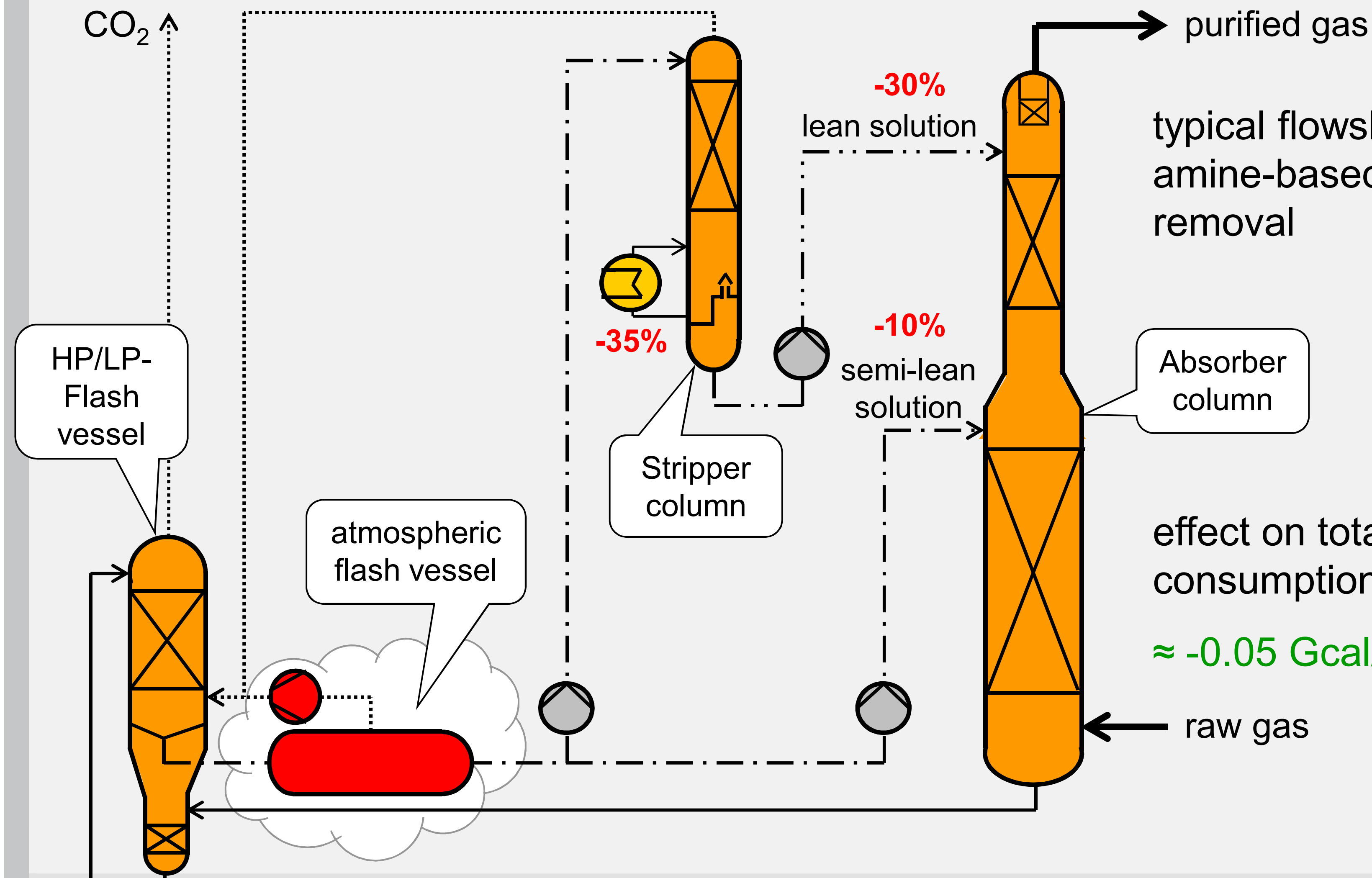
- e.g. flue gas at stack, synthesis waste heat to cooling water, ...
- exemplary measures:
  - extended use of primary reformer flue gas heat to lower the stack temperature:
    - combustion air preheating
    - higher preheating temperatures of feed/steam and process air
    - optional: integration of a pre-reformer with re-heating in flue gas duct

    ... all to utilize waste heat for process requirements
  - raise more HP steam and minimize heat loss to cooling systems:
    - 2 converter, 2 boiler synthesis loop
    - lower temperature difference in synthesis gas/gas heat exchanger

Options for saving energy (2)
Extended physical desorption in CO_2 removal unit

- Regeneration of solvent (here: aMDEA) is typically done with:
  - 2-stage physical desorption (HP/LP flash) for semi-lean solution
  - stripper column for lean solution
- Better regeneration by lower pressure possible, but:
  LP flash pressure optimized for CO_2 compressor suction pressure
- Insert atmospheric flash vessel below LP pressure for overall energy saving by:
  - lower solution circulation rate
  - lower reboiler duty
  - mechanical vapour compression

Options for saving energy (2)
Extended physical desorption in CO_2 removal unit



typical flowsheet of amine-based CO_2 removal

effect on total energy consumption:

≈ -0.05 Gcal/t NH_3

Options for saving energy (3)
Optimum efficiency energy conversion

- Steam reforming process must release some waste heat
- Raising HP steam is a good option to utilize this heat for power generation (lower steam pressure means lower efficiency)
- Remaining power demand can be provided by:
  - enlargement of the steam cycle duty by:
    - extra reformer firing
    - steam from auxiliary boiler

    cycle efficiency: ~30%
  - combined cycle power plant (incl. gas turbine) serving the whole plant complex with steam and electric power:
    - cycle efficiency: >40% (up to 60% in large scale power plants)
    - energy saving:
      - advantage of **0.25 Gcal/t_{NH3}** in exemplary NH_3 plant (due to changed energetic value of steam and power)
      - similar savings in the rest of the complex (urea and utilities)

Options for saving energy (4)
Use of energy-efficient machinery

- Recent proposal data from reputable vendors (same project):

		Vendor 1	Vendor 2
Synthesis gas compressor turbine	HP steam inlet MP steam extr. Δ MP steam Δ consumption figure *1	250,400 kg/h 181,700 kg/h	250,400 kg/h 190,100 kg/h + 8,400 kg/h **- 0.08 Gcal/t**
Refrigeration compressor turbine	MP steam inlet Δ MP steam Δ consumption figure *1	34,900 kg/h	31,824 kg/h + 3,076 kg/h **- 0.03 Gcal/t**

*1: MP steam rating: 3300 kJ(prim. energy) / kg(steam)

- Selection of machinery is also a question of energy consumption

Options for saving energy (5)
Reduced pressure drop

- Pressure drop from outlet steam reformer
  to inlet synthesis gas compressor usually ranges from 6 to 9 bar

- Loss is to be compensated by synthesis gas compressor
  Example:

pressure drop of	**1 bar**	
corresponds to about	**0.007 Gcal/t_{NH3}**	primary energy cons.
or to a net present value of	**~600,000 USD**	

Conditions as on slide no. 3

- Effect on the overall consumption figure is small

- Consequently, it makes sense to find the optimum pressure drop with respect to total cost (capex + opex)

Comparison of consumption figures
Checklist

- Energy consumption: important parameter to assess the economic value of a plant
- Just comparing numbers of energy consumption might be misleading because of:
  - Climatic conditions: lower energy consumption can be the consequence of lower ambient temperature, not of a "better" process
  - Selection of boundary: for different projects, the boundary can be selected differently – recommendation: include
    - condensate stripper
    - BFW pump power
    - refrigeration power for process
  - Credits for import / export streams: sometimes handled differently

See paper for more examples

Summary

- Energy consumption of a typical modern plant is already rather low:
  - >60% of energy consumption converted into product
  - losses difficult to reduce
- Some potential in:
  - minimization of heat losses (e.g. reformer flue gas heat)
  - extended physical desorption in CO_2 removal unit
  - high efficiency supply of mechanical power (combined cycle for producing steam and electric power)
  - efficiency of machinery
  - etc. ...
- Be suspicious in case very low consumption figures are stated without obvious process improvements
  - is the balance correct? (boundary, valuation of import / export, ...)
- Lowest energy consumption is <u>not</u> the economical optimum: consider capex + opex

Thank you
for your attention!

Questions?

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