Energi efficiency in the process industry

Some possible approaches

Reidar Arneberg, Tel-Tek

Prosin Fagseminar og workshop 13.08.2013

Smart Manufacturing
- with focus on the industrial need

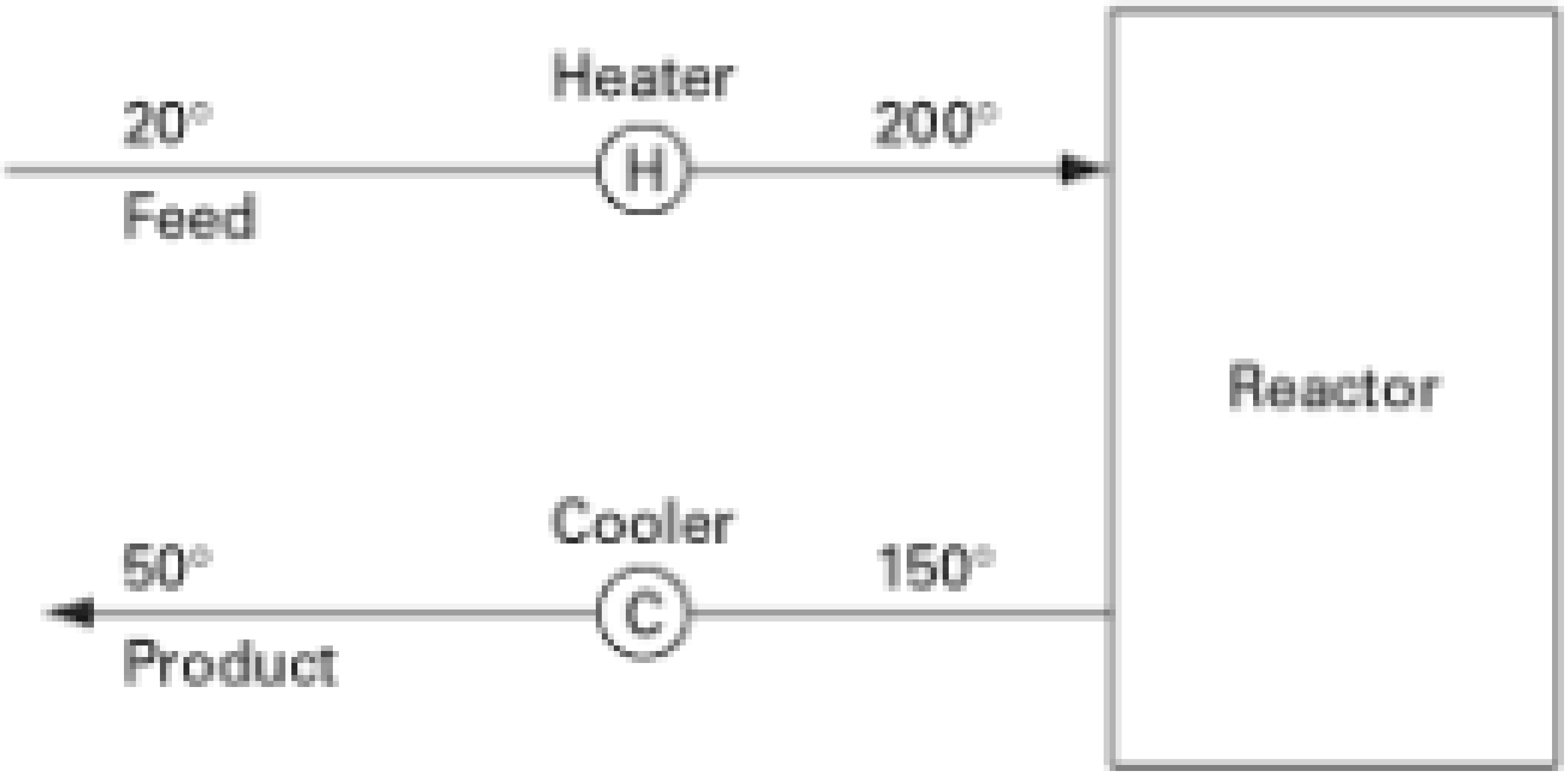
- Tel-Tek
- University of Bergen
- UoW/CPAC
- ……

Partners at present:
Jotun
Eramet
Diplom-Is
Weifa
Kebony Products
Biomar
Axis-Shield
GC Rieber Oils
Skretting

- Development of competence (courses in combination with coaching)
- Specific projects at client sites with large potential
- Students/recruitement (masters, post docs, industry PhDs, PhDs)
- Smart sensors and instrumentation including soft sensors
- Data Quality

Energy efficiency – Process industry

Energy efficiency – Process industry



How to release the Energy efficiency potentials?

Energy efficiency – Process industry

Possible approaches:

- Reuse of the waste heat
- Process understanding, control and optimization
- PINCH analysis
- Process intensification

Energy efficiency – Process industry

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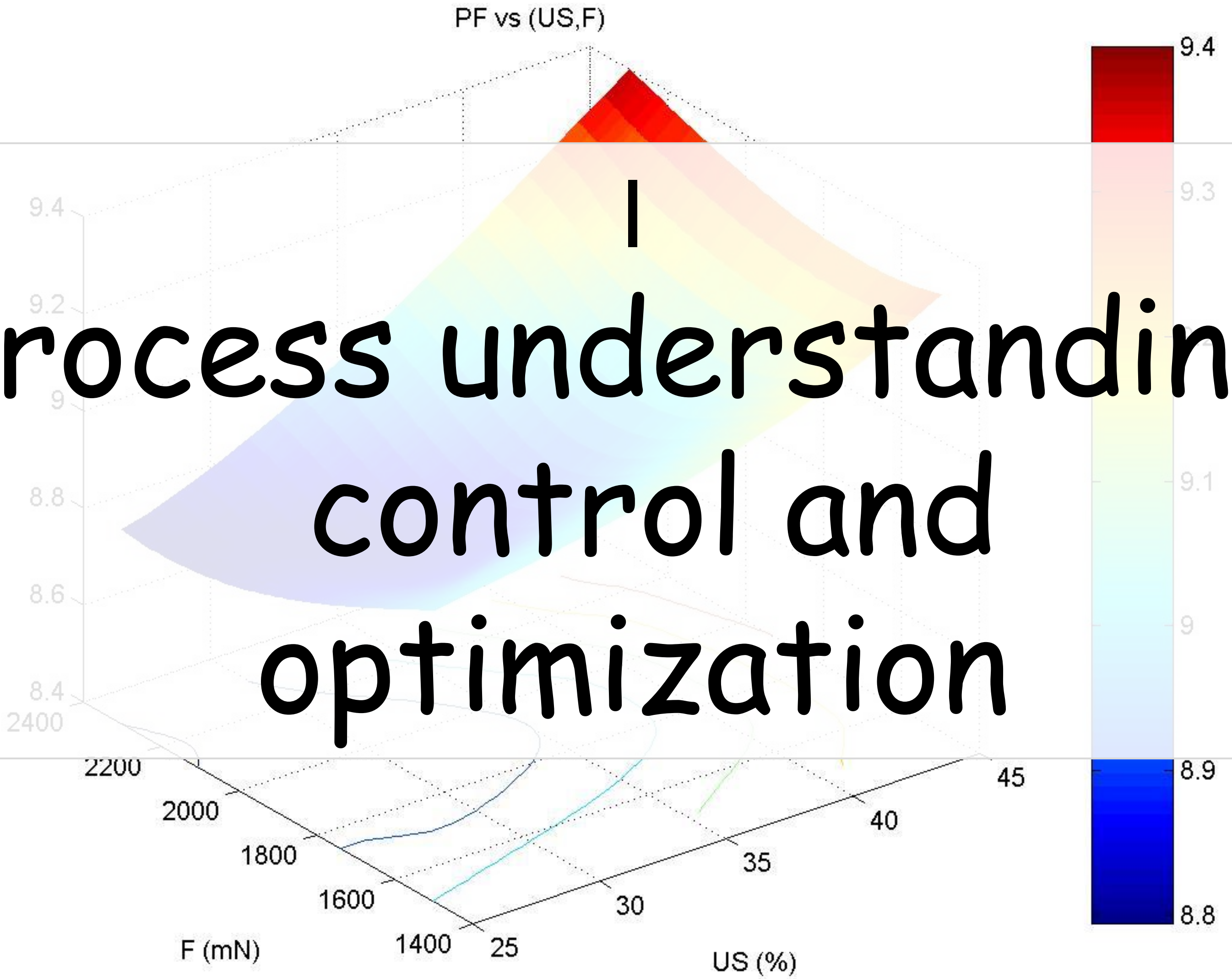
Process understanding, control and optimization



Process understanding and optimization

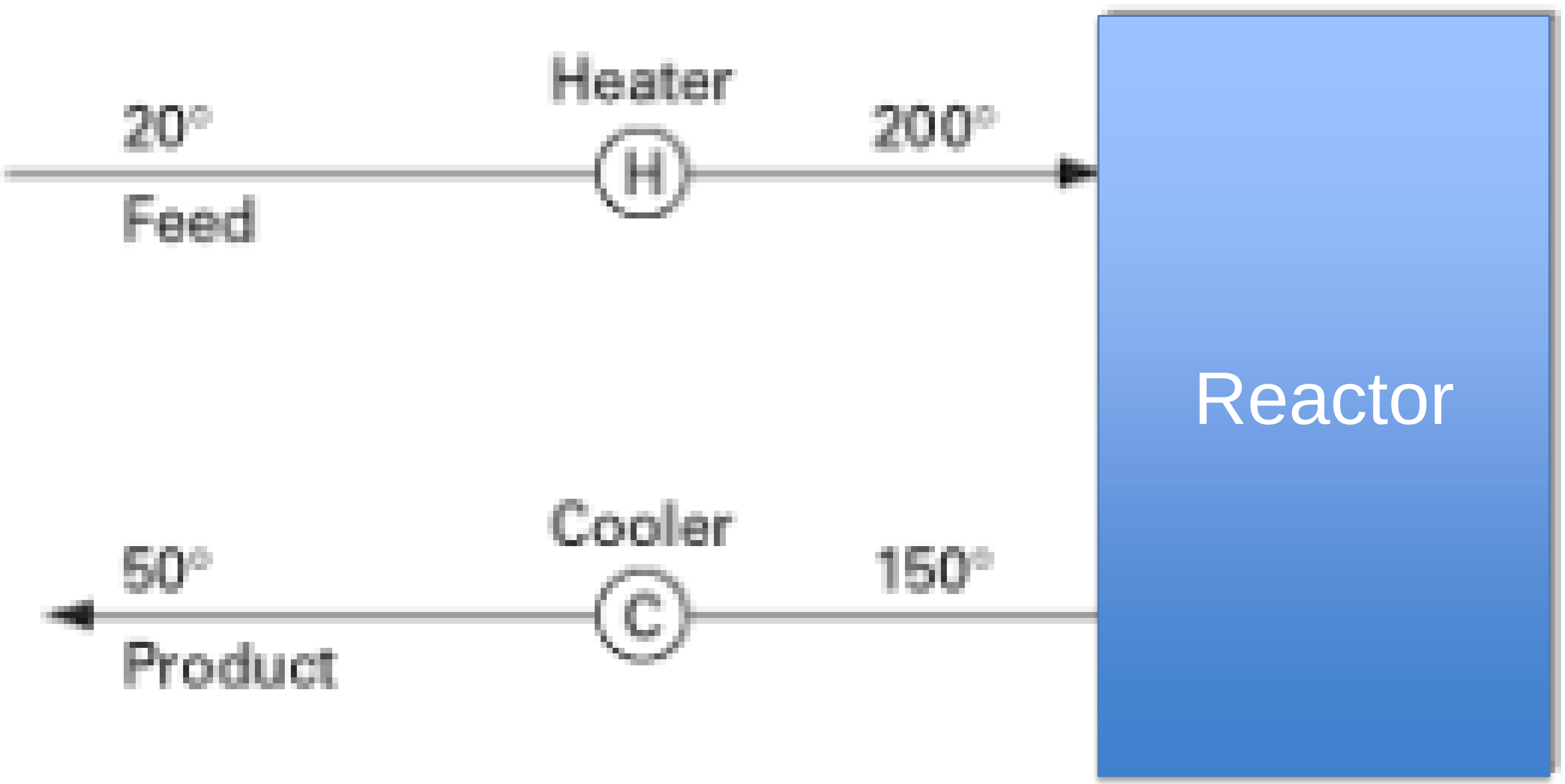
Energi21
Energieffektivisering i industrien

FoU-mål 1a: Utvikle **bransjeoverskridende** teknologi og kunnskap for redusert energibruk og utnyttelse av overskuddsvarme

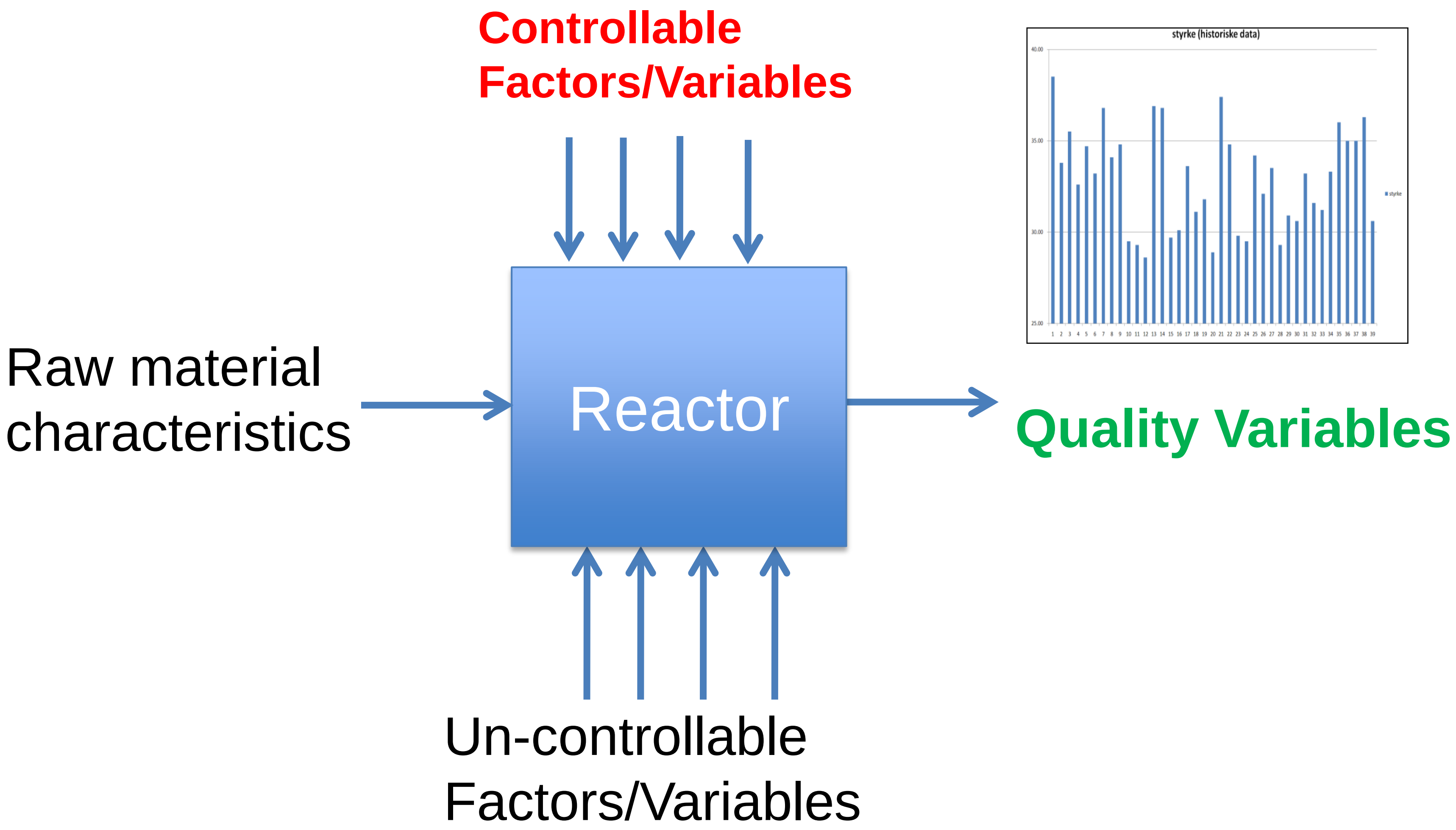
FoU-utfordringer 1a:

1a.5: Utvikle kompetanse innen: • Design av energieffektive prosesser • Prosessregularitet og sikkerhet • Energioptimal prosessovervåking og– regulering
1a.6: Utvikle metodikk og verktøy for analyser: • Prosessanalyser • Analyser av energikvalitet • Økonomiske analyser • Livssyklusanalyser
1a.7: Utvikle standarder for måling av energieffektvisering/energibruk

Energy efficiency – Process industry



Process understanding and optimization



Process understanding and optimization

The FDA (2004) defined process understanding as: A process is generally considered to be well understood when

1. All critical sources of variability are identified and explained

2. Variability is managed by the process,

3. Product quality attributes can be accurately and reliably predicted over the design space established for the materials used, process parameters, manufacturing, environmental and other conditions.

Process understanding and optimization

A lack of fulfilling these criteria may imply:

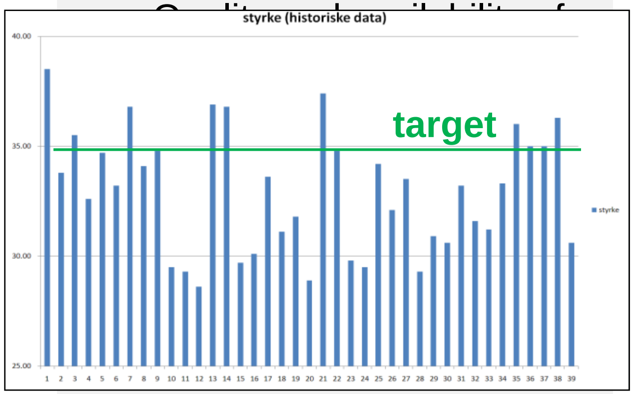
- A significant amount of unintentional variation (waste)

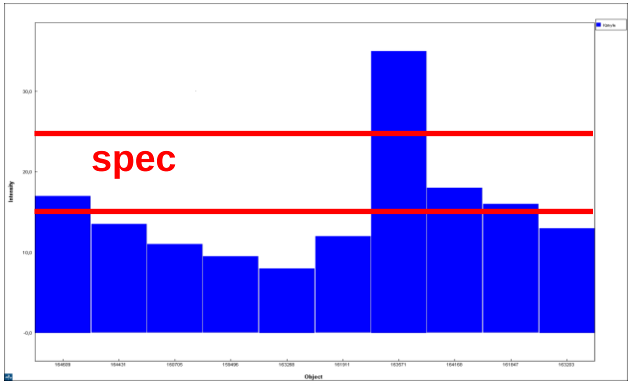
Process understanding and optimization

Strategy for handling these un-intential variation

- even the best in class experience unintentional product/process variations
- un-intentional variations drive cost up and performance down => reduced profitability and competitiveness
- challenges to identify **root causes** in complex systems
- challenges to turn root cause understanding into actionable improvements due to (mainly):

  -lack of data or poor data quality
  -high degree of correlations in process data
  -multiresponse considerations in optimization
  -causality and correlations overlapping
  -lack of model-based approach





Process understanding and optimization

A lack of fulfilling these criteria may imply:

- A significant amount of unintentional variation (waste)
- Unable to reach the "Right-first-time" goal

Prosjekt : Riktig første gangen				Uønsket variation
2012	Antall ikke justert	Antall batcher produsert	% ikke justert	(antall timer sløst)
uke 1	11	17	65%	18
uke 2	17	28	61%	33
uke 3	13	28	46%	45
uke 4	16	31	52%	45
uke 5	17	31	55%	42
uke 6	5	16	31%	33
uke 7	16	25	64%	27
uke 8	11	33	33%	66
uke 9	19	30	63%	33
uke 10	20	29	69%	27
uke 11	16	21	76%	15
uke 12	16	30	53%	42
uke 13	20	30	67%	30
uke 14	14	25	56%	33
uke 15	8	25	32%	51
uke 16	19	52	37%	99
uke 17	25	43	58%	54
uke 18	13	27	48%	42
uke 19	21	38	55%	51
uke 20	3	13	23%	30

Process understanding and optimization

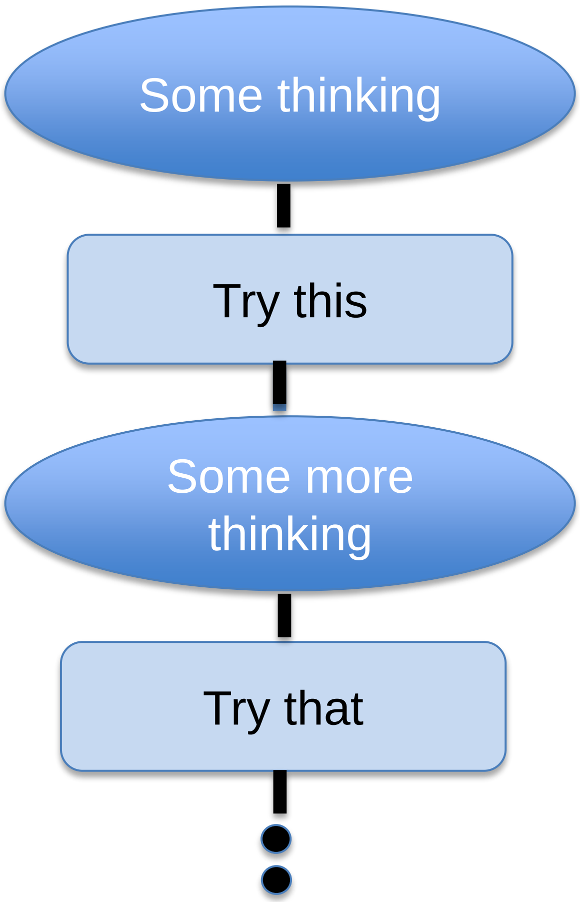
A lack of fulfilling these criteria may imply:

- A significant amount of unintentional variation (waste)
- Unable to reach the “Right-first-time” goal
- Non optimal use of the raw materials
- In general a non-optimal process (yield, energy use,..)

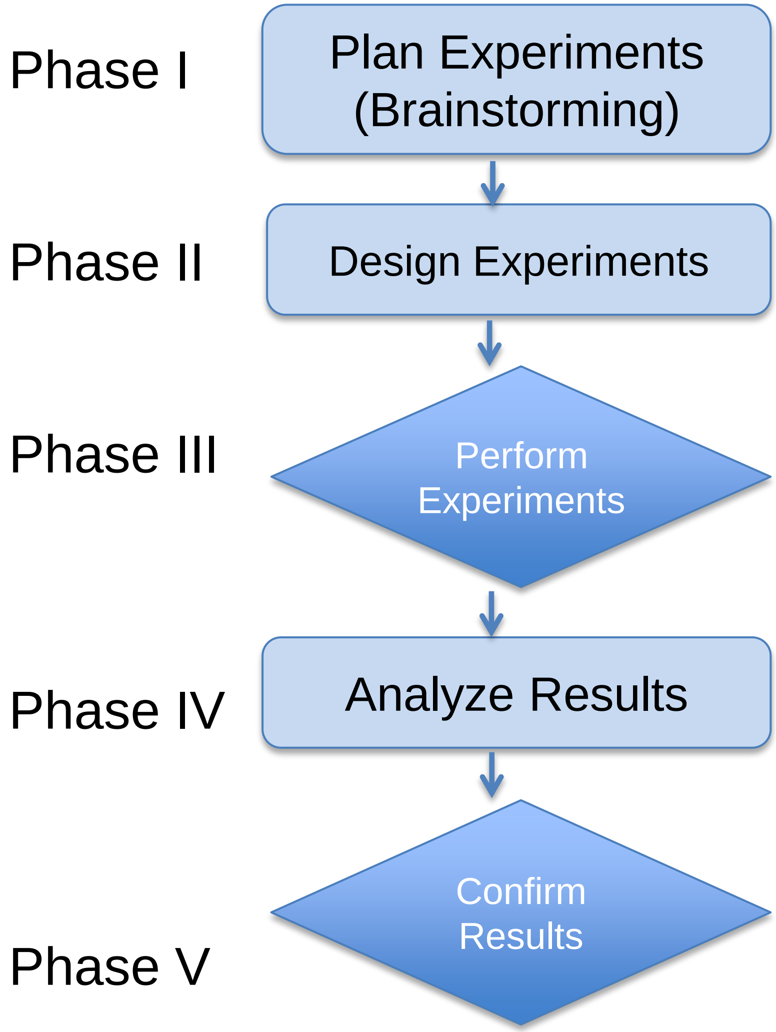
A potential for energy efficiency

Process understanding and optimization

Most used approach



Best Available Technology (BAT)



Process understanding and optimization

Success factors

- Use of Experimental Design
- Reliable/robust and contineous measurements of all important process variables (including raw material characterization)

Multi-response optimization

Plant Profit = + Σ (Product rate X Product Value)
- Σ (Raw Material usage X Raw Material cost)
- Σ (Energy usage X Energy cost)
- Σ (Emission cost)
- Σ (Maintenance cost)
- Σ Others

Energy efficiency – Process industry

Process understanding and optimization

“Diagnosis and reduction of deposition of coke in coils”

Background

- Thermal cracking of the residue (heavy fraction) from the fractionation tower represents an important process in most oil refineries
- Cracking temperature is obtained by heating the residue in an oven. High temperatures (>4-500° C) on the coils leads to deposition of coke on the inside of the coils
- Measuring process variables problematic
- During time this leads to an isolating layer requiring more fuel, increasing temperature on the coils and, eventually, full stop for cleaning and maintenance

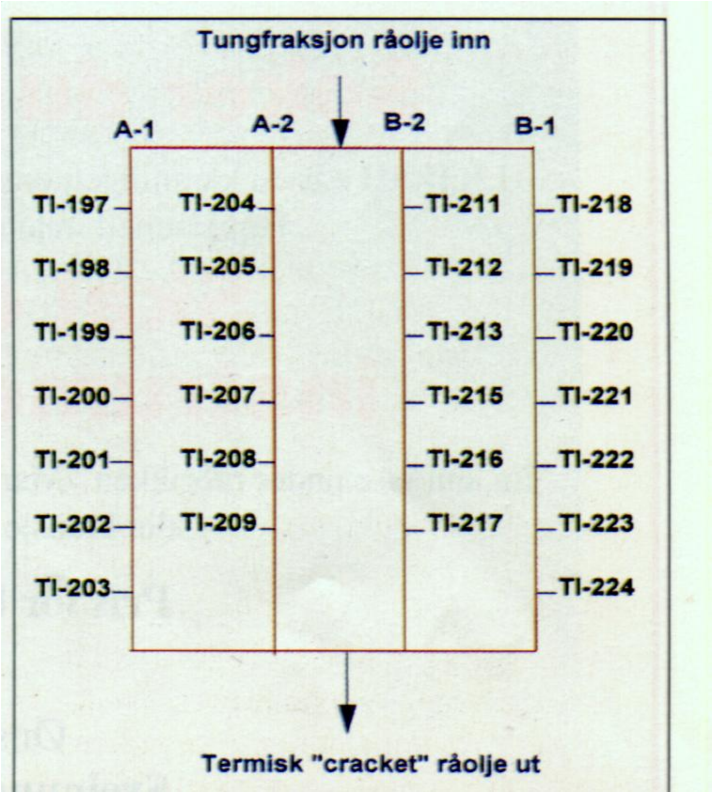
Economic loss factors

- Gradually increased use of energy during the time between start-up and stop
- 5-7 days lost production due to cleaning and maintenance

Aim of project

- Find a way to monitor coke - deposition
- Identify the factors important for the deposition
- Develop and implement a new regulation strategy that can decrease deposition rate

Oven with temperature elements



- The oven contains 4 coils; A-1, A-2, B-2, and, B-1
- The residue is divided into 4 corresponding streams
- Along each coil the outside temperature is measured on 7 locations

Energy efficiency – Process industry

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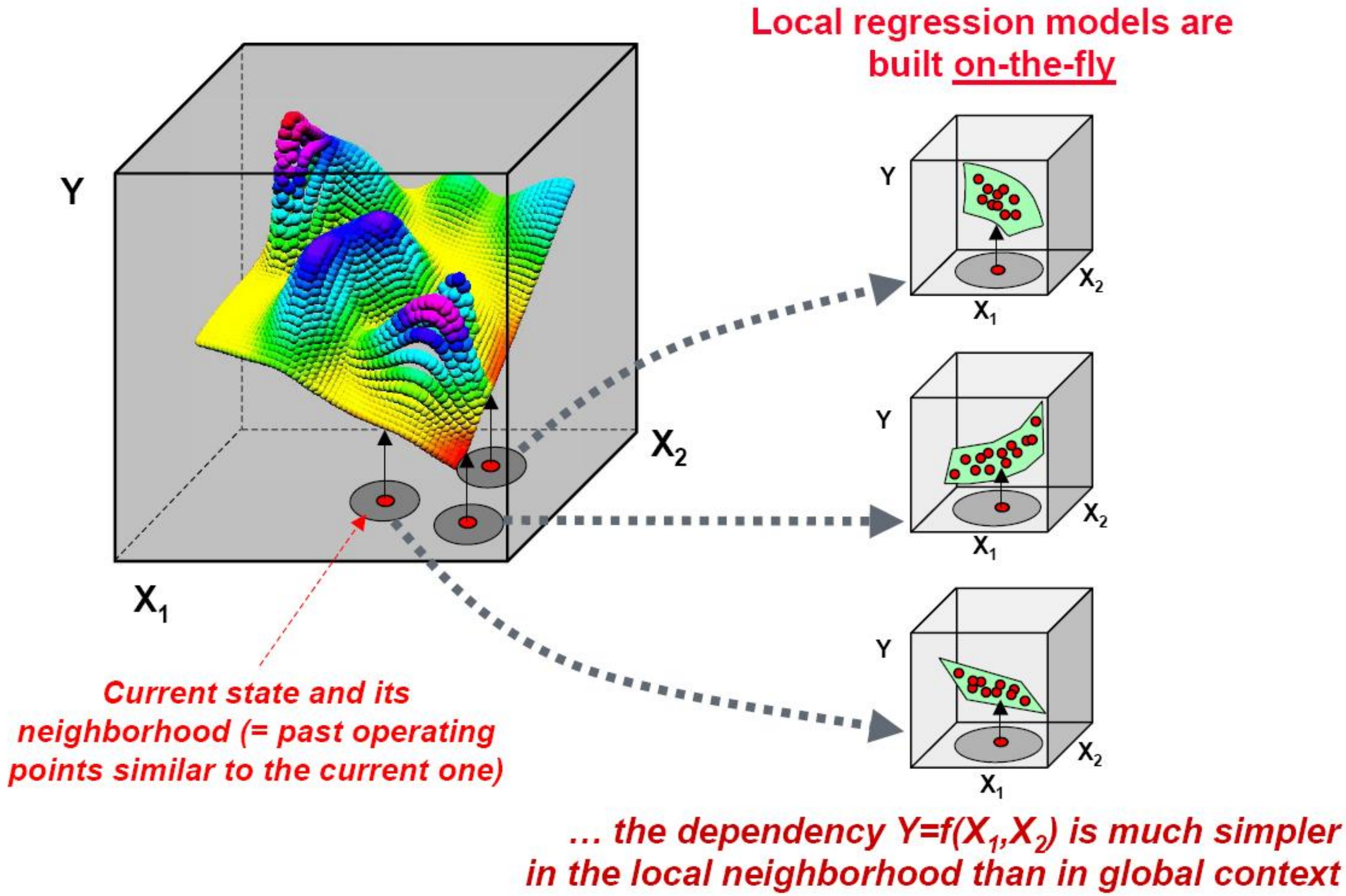
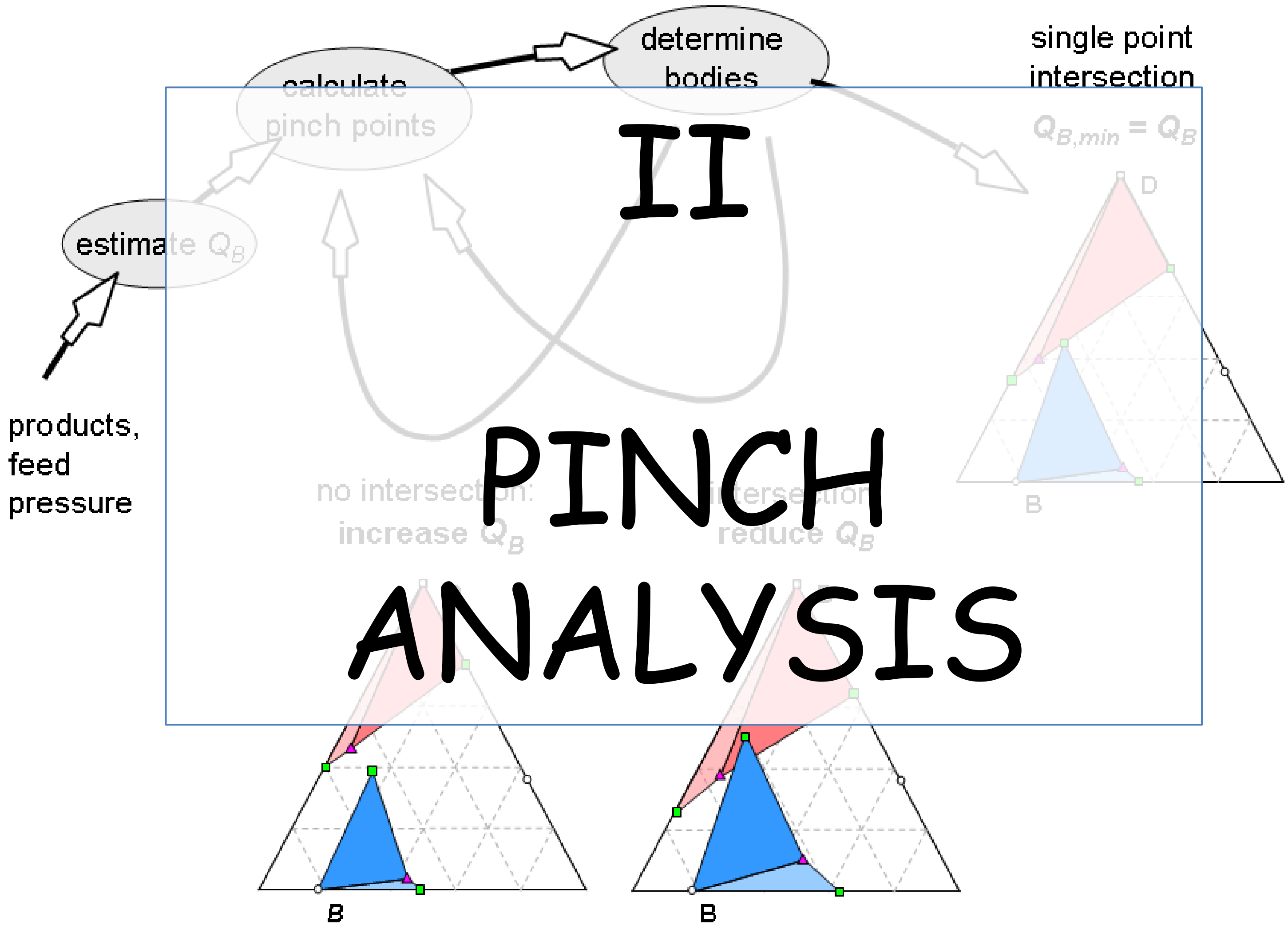


II PINCH ANALYSIS



PINCH Analysis

Process Integration refers to the analysis and optimization of large complex industrial process and are defined as:

> *All improvements made to process systems, their constituent unit operations, and their interactions to maximize the effective use of energy, water and raw materials.*

Among Process integration methodologies**, PINCH analysis (PI)** is the most widely used

PINCH Analysis

Pinch Analysis is the most used Process Integration approach.

- It is a practical tool that has been around for 30 years and it is used to improve efficient use of energy, hydrogen and water in industrial processes (*Energy pinch, Water pinch and Hydrogen pinch*)
- Used in design and modification phase
- Relatively easy to use software are available supporting the method.

PINCH Analysis

PINCH Analysis is a methodology for systematically analyzing chemical processes and the surrounding utility system based on the First and Second Law of Thermodynamics,

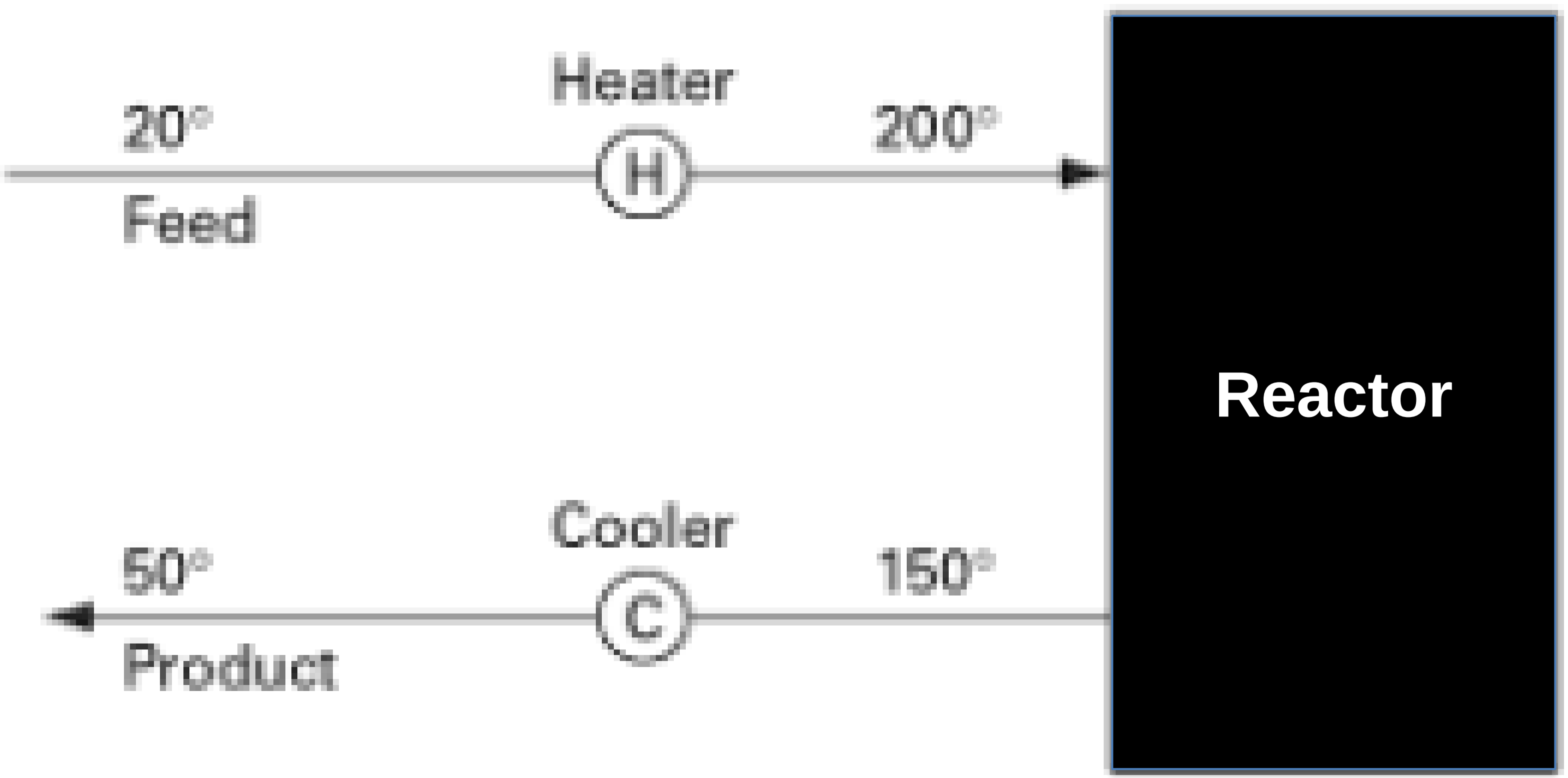
*The **First Law** of Thermodynamics provides the energy equation for calculating the enthalphy changes (ΔH) in the streams passing through a heat exchanger. The **Second Law** of Thermodynamics determines the direction of the heat flow*

PINCH Analysis

The application of Pinch analysis in industrial sectors such as oil refining, chemicals, iron and steel, pulp and paper, petrochemicals, and food&drink, can typical identify:

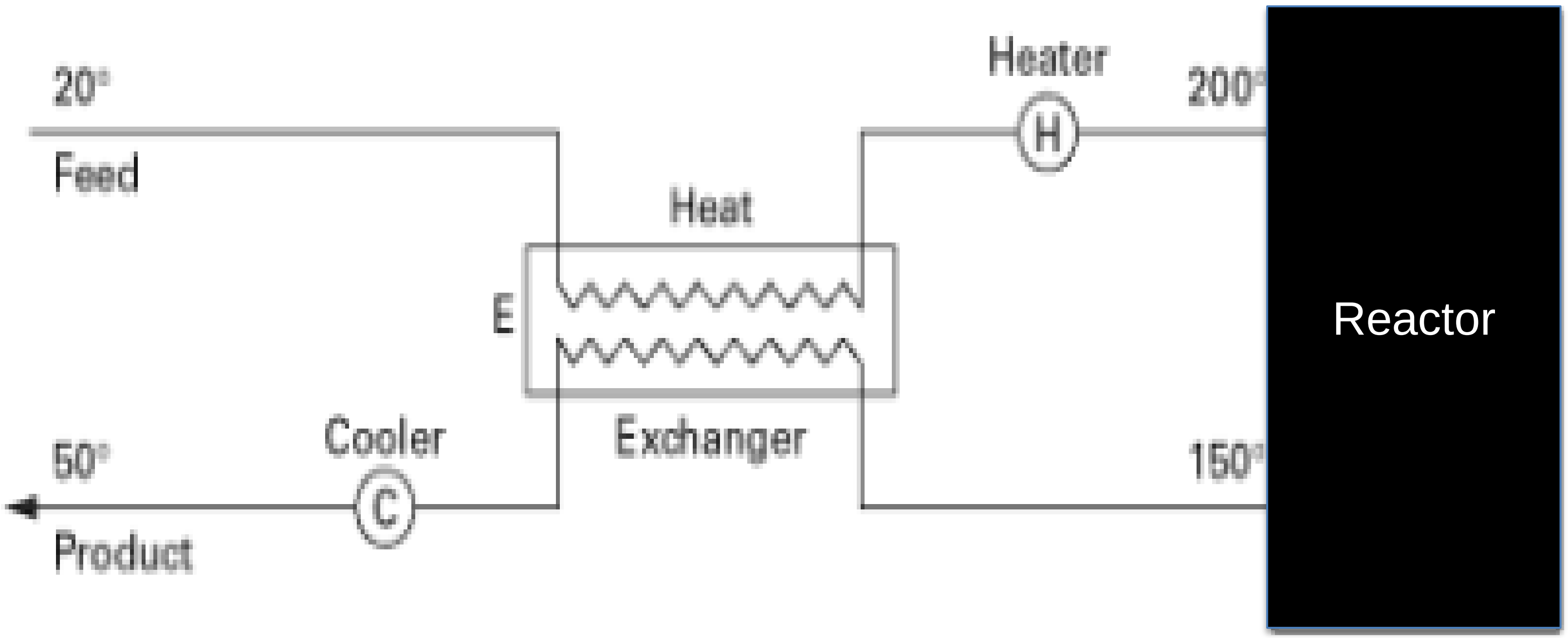
- Savings in Energy consumption: 10% to 35%
- Savings in Water consumption: 25% to 40%
- Savings in Hydrogen consumption : up to 20%

PINCH Analysis



How to release the Energy efficiency potentials?

PINCH Analysis



- How much heat can be recovered,?
- How big should the heat-exhanger be?

PINCH Analysis

One of the pr
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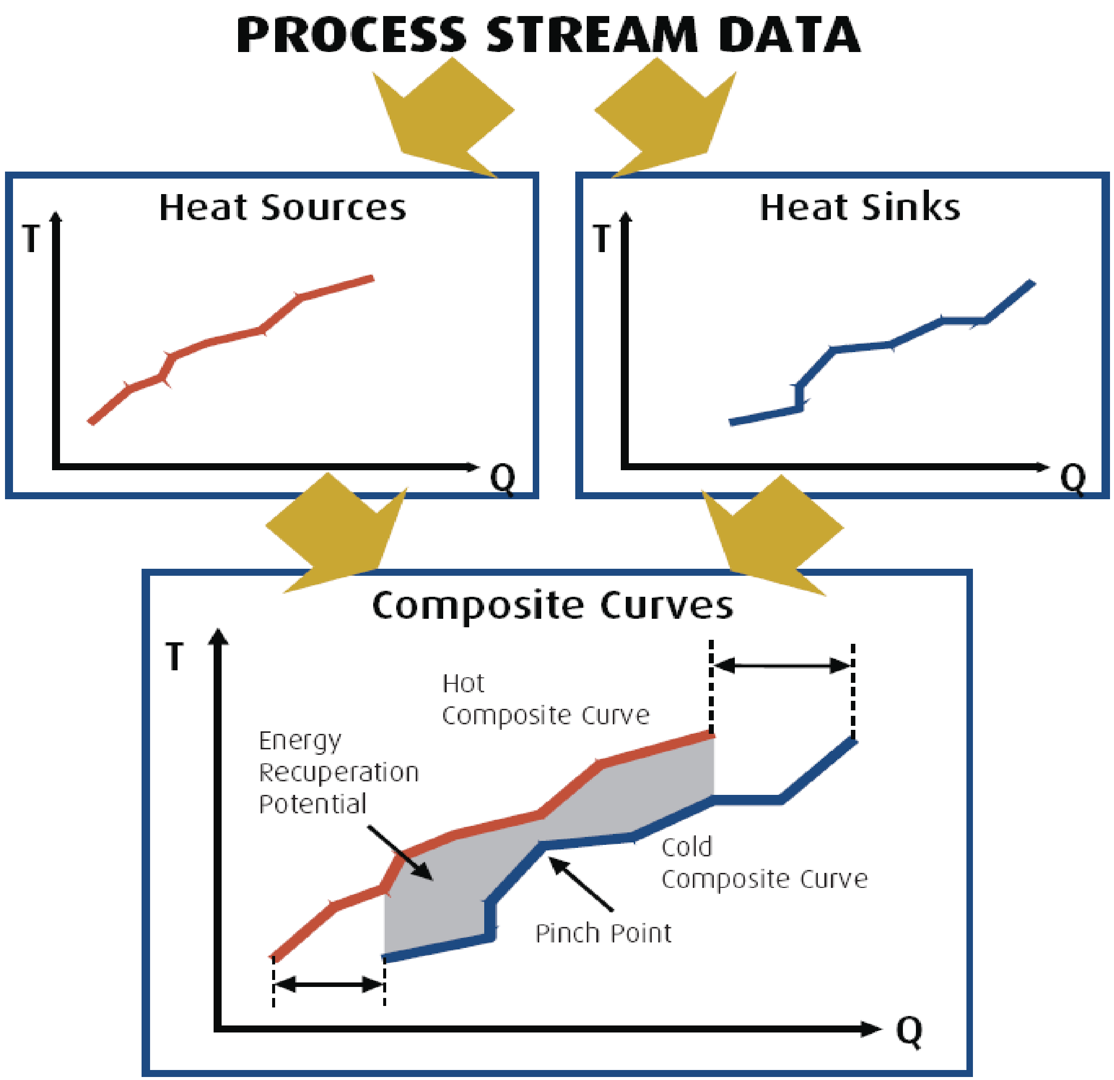
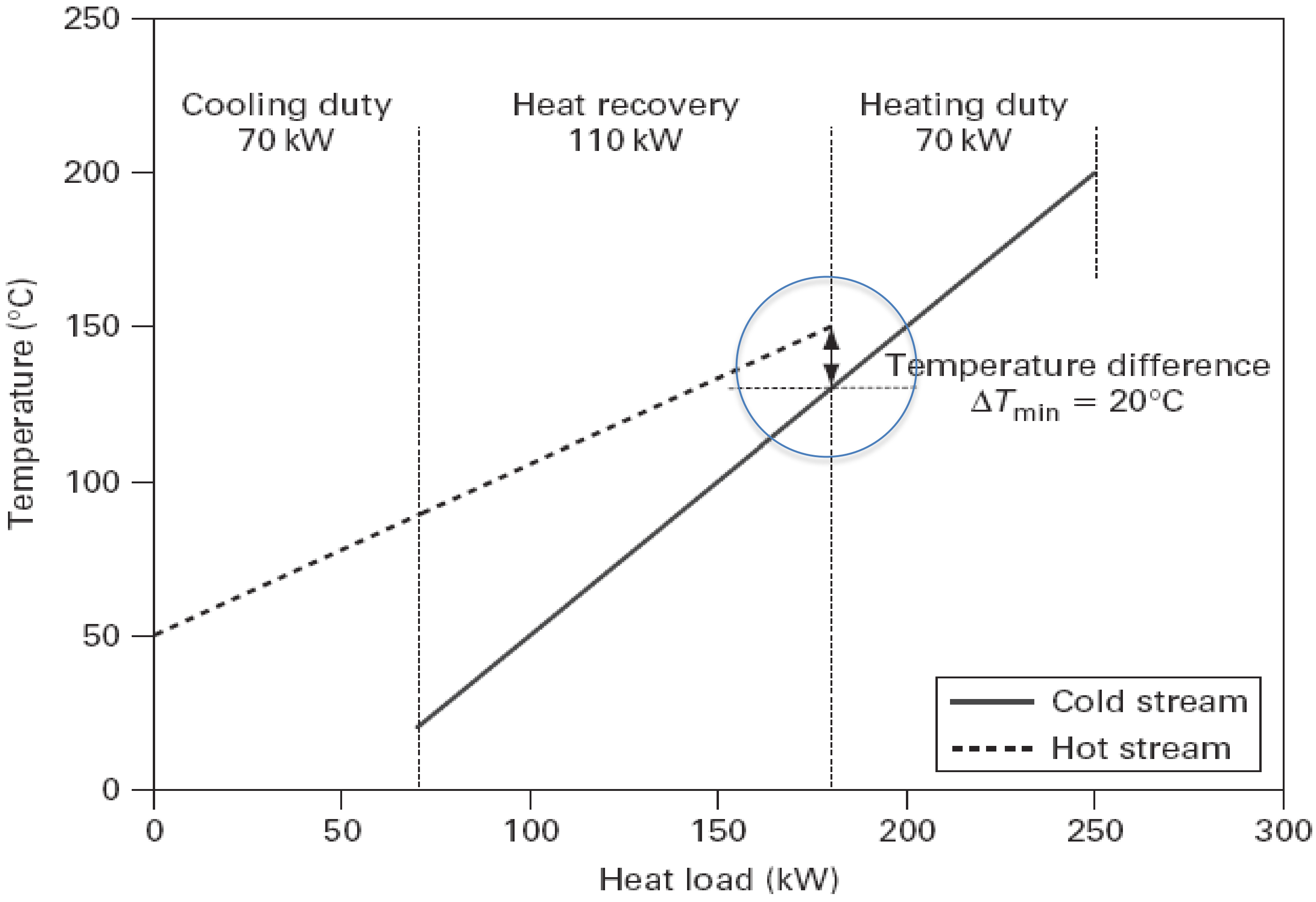


PINCH Analysis - Example

A simple example

	Mass flowrate W *(kg/s)*	*Specific heat capacity* C_P *(kJ/kgK)*	*Heat capacity flowrate* CP *(kW/K)*	*Initial (supply) temperature* T_S *(°C)*	*Final (target) temperature* T_T *(°C)*	*Heat load* H *(kW)*
Cold stream	0.25	4	1.0	20	200	−180
Hot stream	0.4	4.5	1.8	150	50	+180

PINCH Analysis - Example



PINCH Analysis - Example

Selecting ΔT_{min}

As always there is a tı
costs.

As ΔT_{min} increases the
reduced, thereby decr
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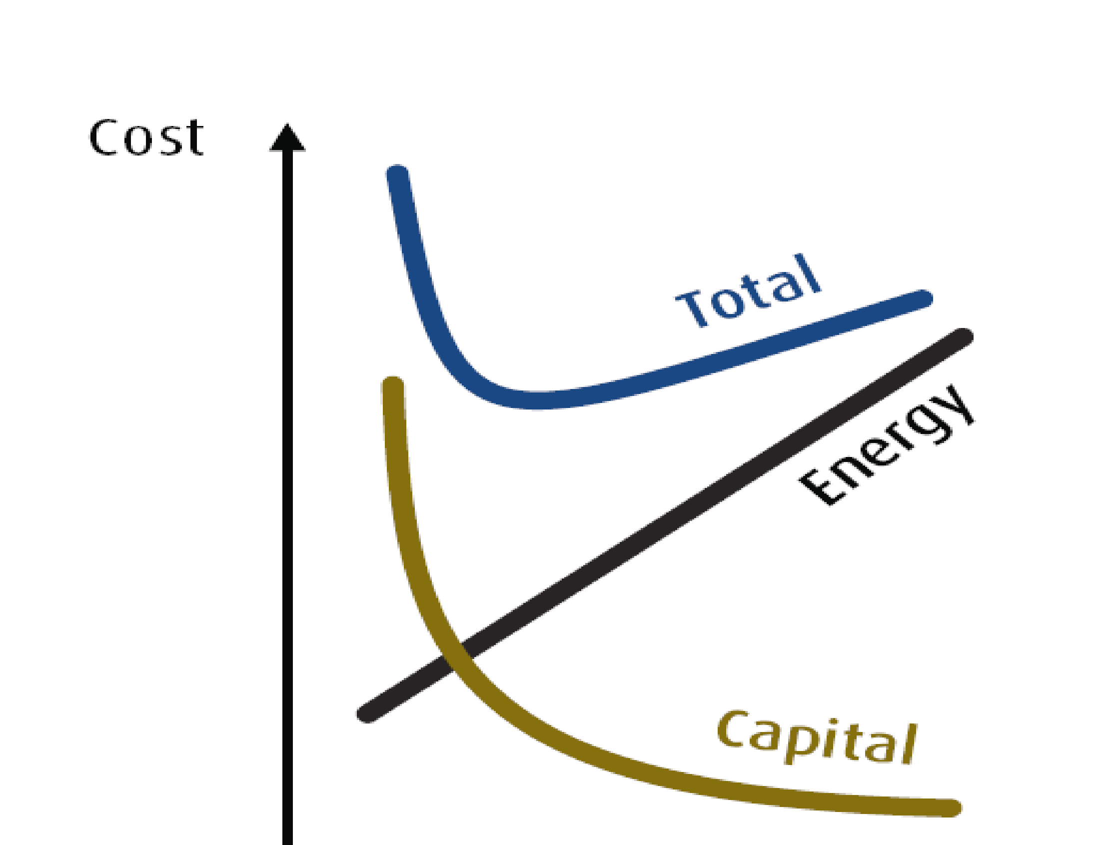
At the same time the
reduced.



Higher energy cost has been offset by the reduced capital cost

Energy efficiency – Process industry

The PINCH analysis is:

- used in the design and modification phase
- complementary to the previous described multivariate process analysis and is to a large extent univariate in its nature focusing only on the heat load.
- a non-optimal process may indicate a larger saving potential

III

Process Intensification

Process control and optimization

G. Agricola, *De Re Metallica*, 1556

Chemical Process Industry, 2006

- THIS IS NOT THE WAY TO BOOST EFFICIENCY
- PROCESS INNOVATION IS CLEARLY NEEDED

Energy efficiency – Process industry

Siste dag for Søderb

Fredag 13. mars kl. 09.01 ble strømmen skru
Dermed opphørte produksjonen i den aller sis
Søderberg-teknologi i Hydro.

13. mars 2009

Neste generasjon aluminiumproduksjon
[Sist endret: 19.06.2013 21:47:07]

Alcoa Norway har to produksjonsbedrifter i Norge, Alcoa Mosjøen og Alcoa Lista. Selskapet er Norges nest største produsent av primæraluminium med en produksjon på 286.000 tonn. Alcoa produserer og leverer aluminium til to forskjellige markeder. Bedriften leverer spesial produkter til aluminium ekstrudering, som igjen leverer aluminium profiler til bil og bygningsindustrien i Europa. I tillegg leverer bedriften flytende støpe legeringer til støperi for bildeler, en unik kobling mellom produsent av aluminium og bildeler. Alcoa eier og driver også en anodemassefabrikk i Mosjøen som leverer til verket i Mosjøen, samt til Alcoa Fjardaal på Island.
www.alcoa.com/norway

ALCOA Alcoa Norway

Intervju med Kai Rune Heggland, direktør for Alcoa Norway

Karbotetermisk produksjon er en helt ny prosess som har vært forsket på over tid. Hva er status?

Karbotermisk produksjon har vært forsøkt ved Elkem Research i Kristiansand i flere år, og i forbindelse med at Alcoa overtok 100% av

- 30% lavere energiforbruk
- Ingen avfall
- CO_2-utslippene kan bli eliminert ved å bruke CO_2 i annen industriproduksjon
- Betydelig lavere drifts- og investeringskostnader
- Stor fleksibilitet, størrelse og drift

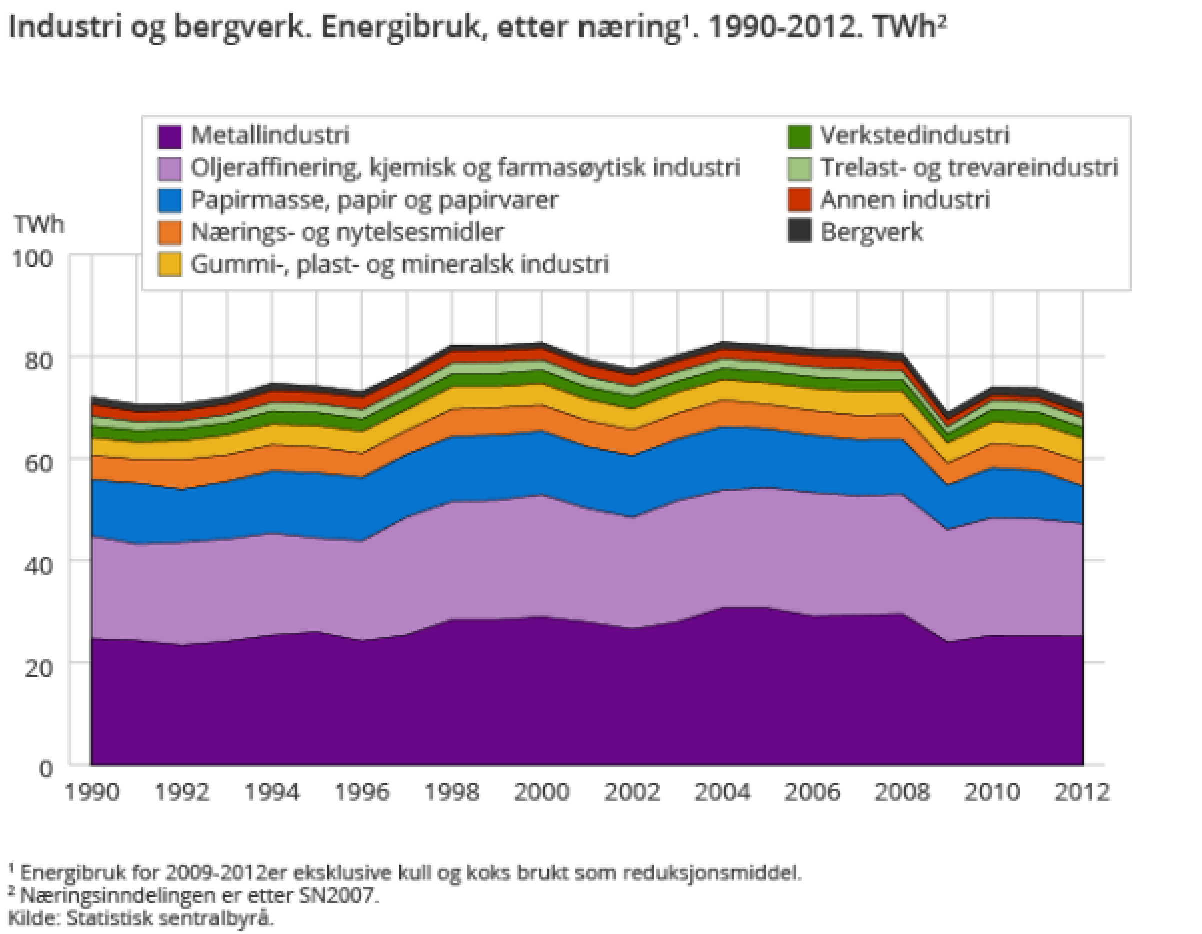
Energy efficiency – Process industry

HEMMELIG PROSESS: Sivilingeniør Ole H. Mykland har hatt ansvaret for å kjøre forsøkene med den nye karbotermiske prosessen. Roberta Höglund sørger for at den intellektuelle kapitalen tas vare på og forvaltes korrekt. Foto: Anders J. Steensen

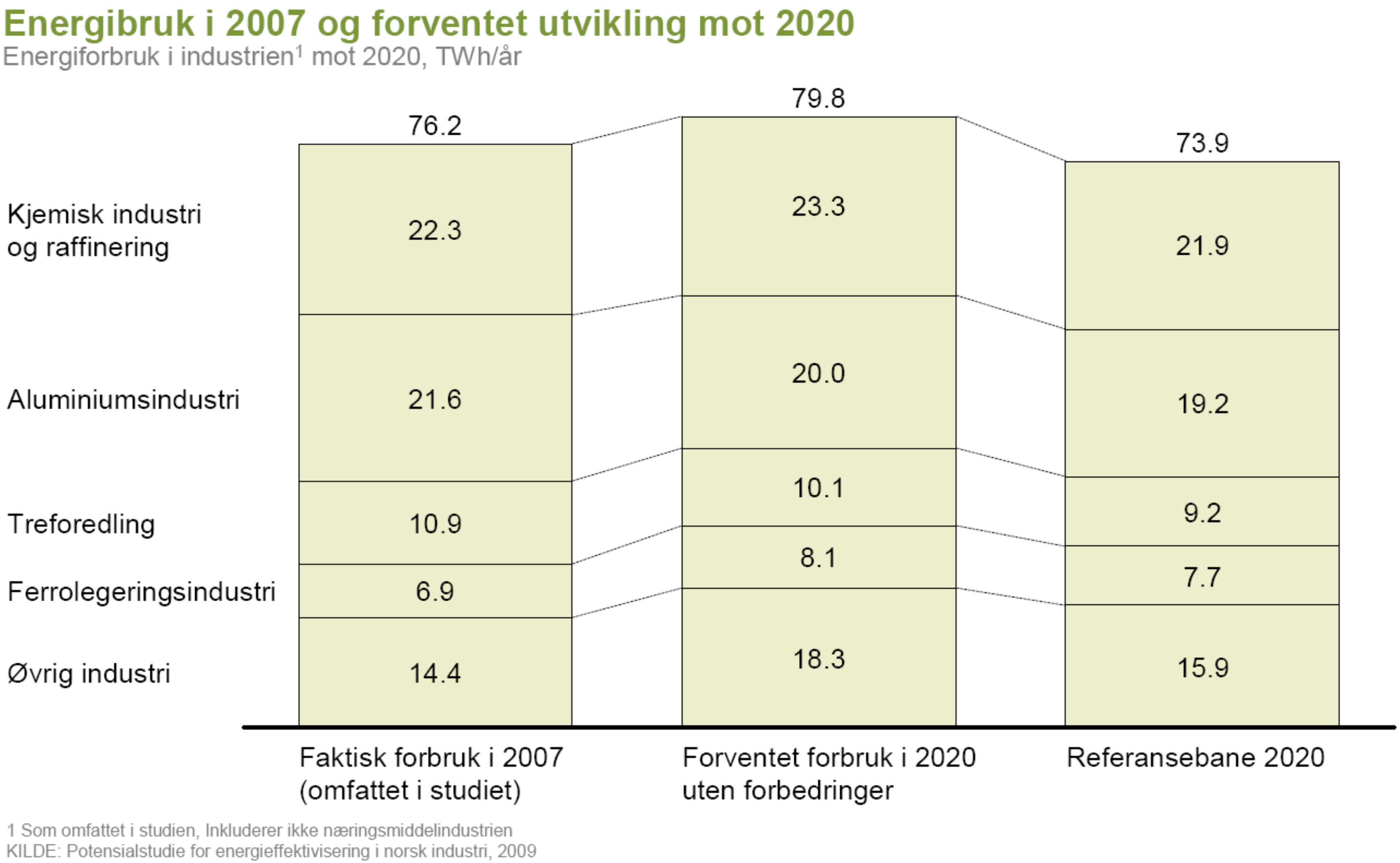
Lager aluminium med 30 % mindre energi

Forskerne ved Elkem Research utvikler nå en ny framstillingsmetode for aluminium som kan redusere energiforbruket og redusere plassbehovet for nye aluminiumsanlegg betydelig. Lykkes Elkem, kan verdens første

Energy efficiency – Process industry



Energy efficiency – Process industry



Energy efficiency – Process industry

Målet er å doble produksjonen, redusere CO_2-utslippene med 90 prosent og energi-effektivisere med 60 prosent.

Bygger ny ovn
Planen er å bygge en ny ovn, som tidligst kan være ferdig i 2017. Der vil prosessen med å foredle råvaren til titandioksid og høyrent støpejern skje ved hjelp av hydrogen, og ikke kull slik tilfellet er i produksjonen nå. Deretter skal den nåværende ovnen bygges om til gassprosess også.
- Vi vil bruke 100 millioner bare på utredninger, teknologiutvikling og pilotskalaforsøk for i Tyssedal. Det er vi i gang med allerede nå, sier Grande.
- Dette er det største investeringsprosjektet i norsk prosessindustri på lang tid.

rder

Process control and optimization

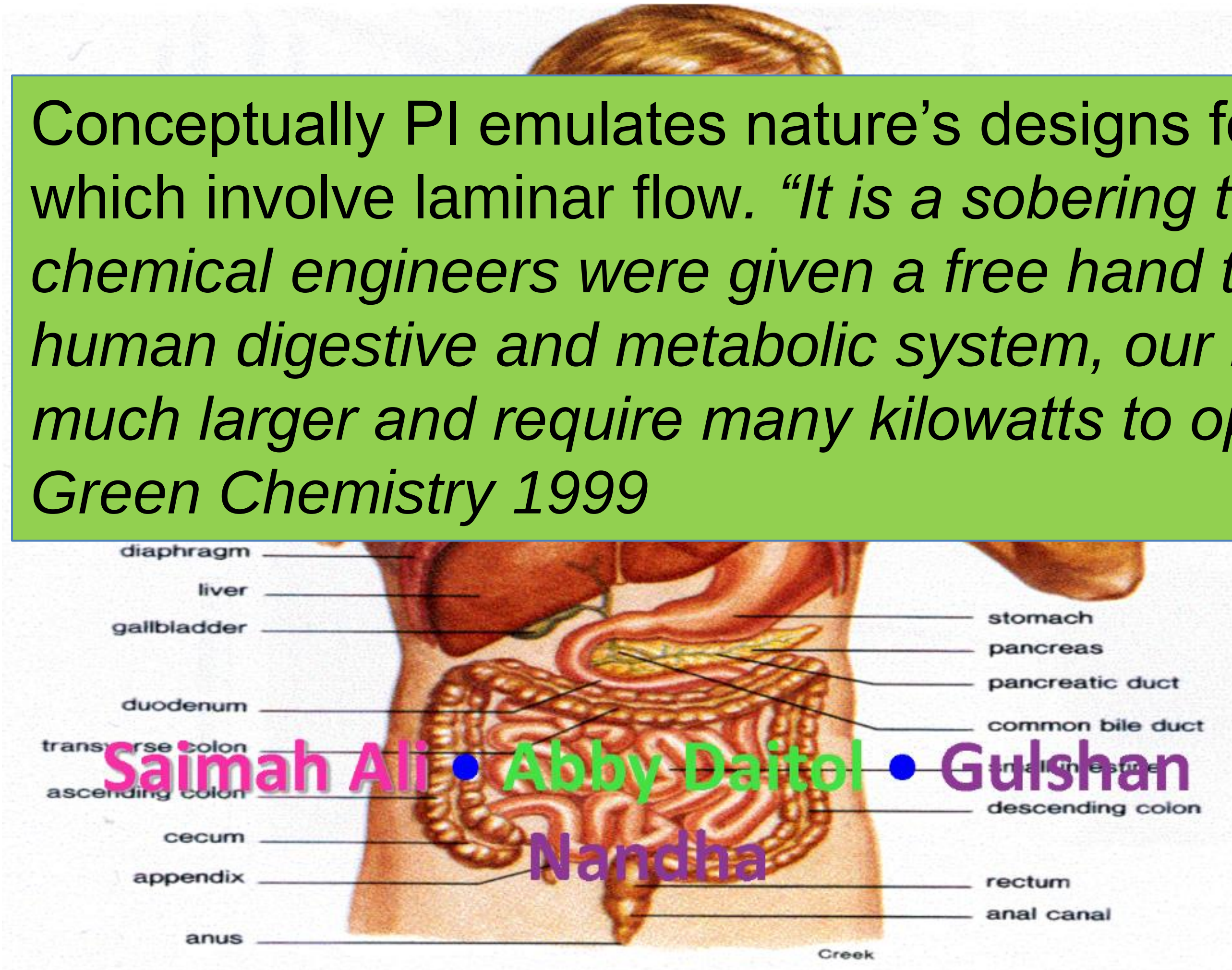
Definition of Process Intensification

A set of often radically innovative principles ("paradigm shift") in process and equipment design, which can bring significant (more than factor 2) benefits in terms of process and chain efficiency, capital and operating expenses, quality, wastes, process safety, etc.

(European Roadmap of Process Intensification, 2007)

Energy efficiency – Process industry

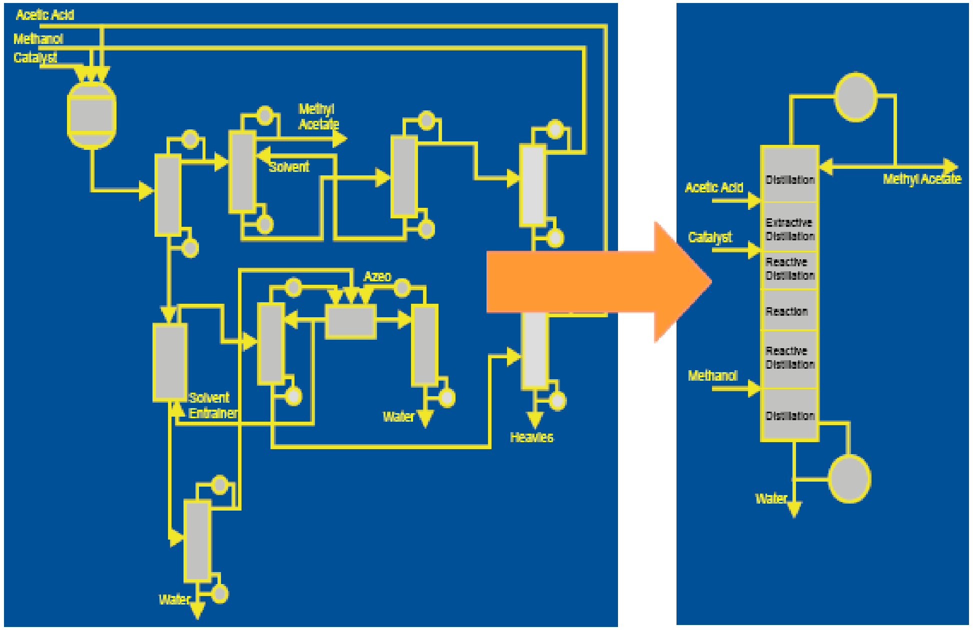
Conceptually PI emulates nature's designs for processing which involve laminar flow. *"It is a sobering thought that if chemical engineers were given a free hand to design the human digestive and metabolic system, our bodies would be much larger and require many kilowatts to operate them."*
Green Chemistry 1999



Energy efficiency – Process industry

PI benefits

Energy saving: 85% (Eastman Chemical, methyl acetate process)



Possible energy savings due to PI: **20 – 80%**

Source: Arthur D. Little report for SenterNovem, 2006

Energy efficiency – Process industry

The flow pattern in these micro-reactors is **laminar** and there is no sense in trying to increase turbulence by dissipating more energy.

Two phase laminar flow leads to higher mass transfer than conventional turbulent reactors. In fact, mass transfer is increased by reducing the energy dissipation.

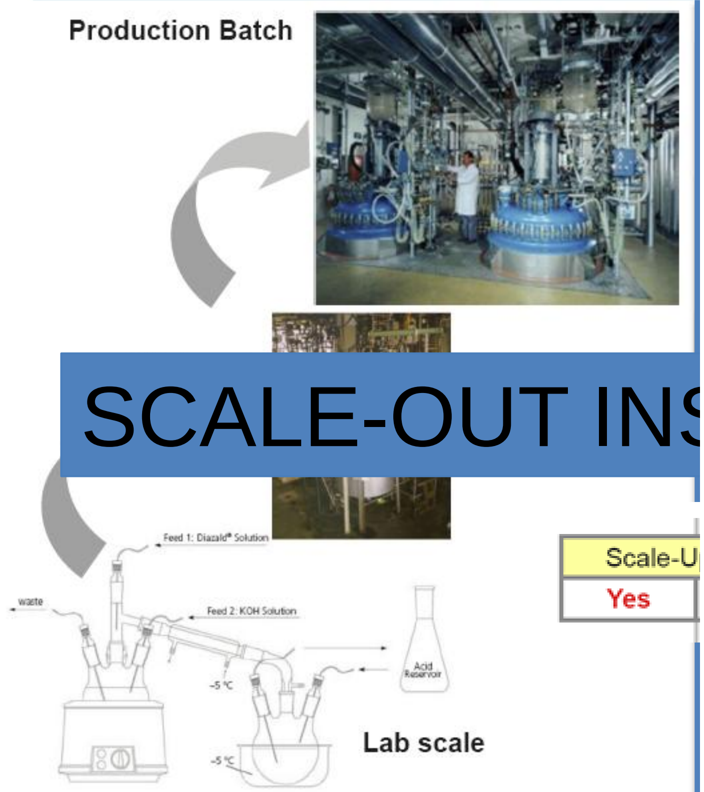
This is achieved by interactions at a molecular level that are maximized by flowing fluids through high surface area equipment.

This technology has broad application over a wide range of manufacturing sectors.

(http://www.youtube.com/watch?v=iSBEy_VN4Uc&noredirect=1)

Energy efficiency – Process industry

Numbering-up Instead of Scaling-up for Production



SCALE-OUT INS

P

From Batch to CFR (continious flow reactor)

Combined use of:

- Micro-reactor technology,
- Miniaturised instrumentation
- Chemometrics

PhD cooper
Olav Bleie

Swern-Moffatt oxidation

The Swern-Moffatt oxidation of primary and secondary alcohols to the corresponding aldehydes and ketones is a useful reaction in organic che

This
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The
flow micro-reactor

Must meet the following requirements:

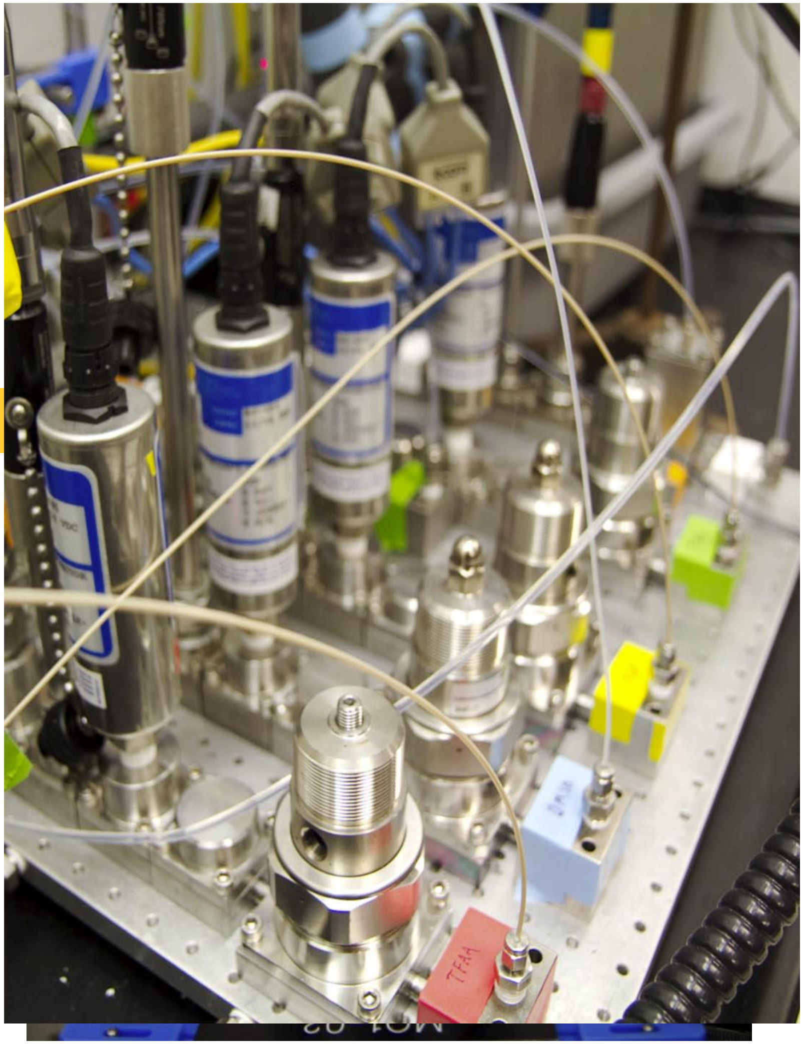
- Offer distinct advantage over batch
  - For example, low temperature or solvent exchange
- Spectroscopically active

Overall Conclusions for batch

- Batch chemistry developed
  - Spectroscopy successfully evaluated
    - Raman and infrared deliver relevant information to reaction progress
  - Hardware evaluated
    - All hardware compatible with chemistry, tested cooling system, reactor plates
  - Data analysis examined
    - Techniques used allowed characterization of reaction progress
- Continuous Flow
  - Understanding of chemistry developed during batch will inform development of reactor system

Continuous Flow Reactors (CFRs)

- Flow cells optimized for continuous production of target compounds.
- **Corning glass micro reactor technology**
- Benefits over batch
  - superior mixing and heat transfer properties (high surface to volume ratio, and turbulent flow)
  - Less random variability
  - Significant reduction of solvent use
  - Precicely controlled temperature and residence times
  - Small and managable volume
  - **Scale-out instead of scale-up – modular approach**
- ml per minute scale
- http://www.youtube.com/watch?v=iSBEy_VN4Uc&noredirect=1



Energy efficiency – Process industry

Conclusion

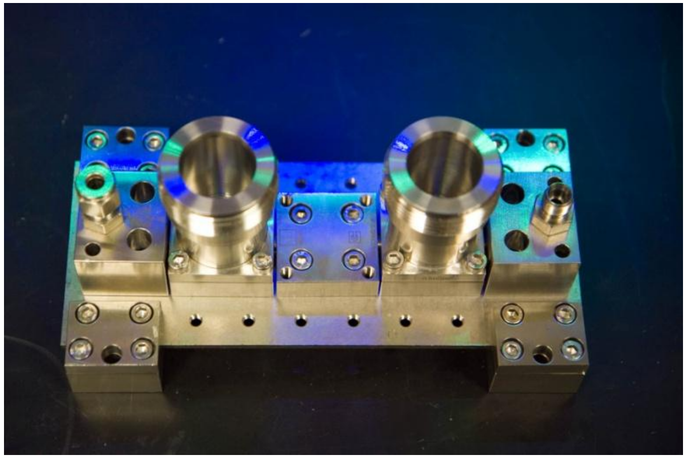
- Not one single approach, use a palette of methods. A multivariate process analysis preferably based on online instrumentation is necessary.

- May be competence intensive

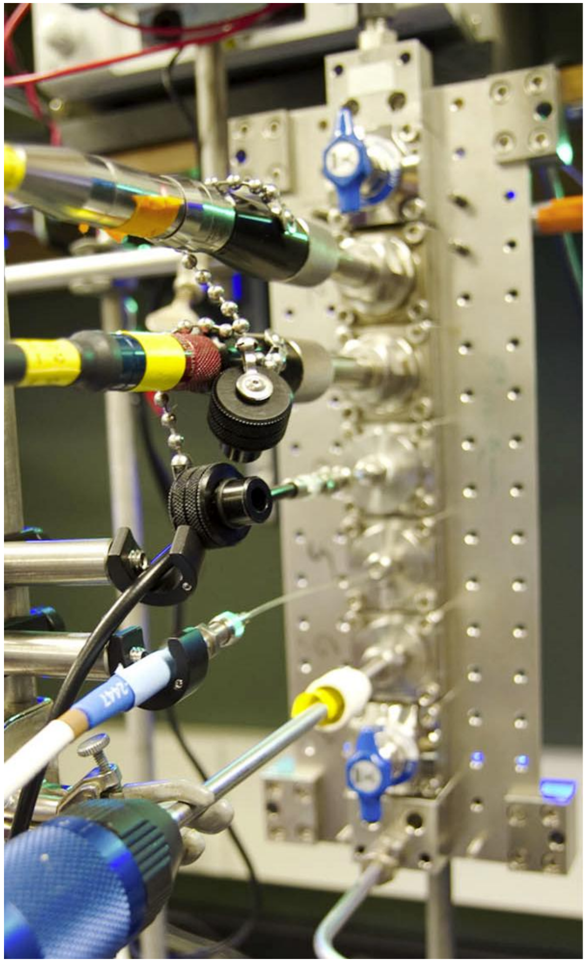
- Think new, before someone else does it!!

The NeSSI platform

- A visual tour



The NeSSI™ system



- Aim: simplify and standardize sample system design
- A modular platform on which sample system components and sensors are mounted.
- Manufacturers: Parker, Swagelok and Circor

Advantages with Nessi™

- Easy to build and operate
  - The LEGO of process analytics
- Reduced build costs
  - Standardisation, reducing design and engineering time.
  - Simplified assembly, reducing manufacturing and construction costs.
- Reduced operating costs
  - Faster and easier maintenance, reducing technician time.
  - Off the shelf parts avaliable