DRYREF™ & SYNSPIRE™

Innovation for HyCO applications

T. Bartesch, K. Wawrzinek, A. Behrens, A. Peschel
Global Syngas Conference, 2020

Making our world more productive

Agenda.

1. BASF & LINDE: Innovation through partnership
2. Process Introduction
3. Case Evaluation
4. CO_2 Footprint
5. Applications
6. Summary

Agenda.

1. BASF & LINDE: Innovation through partnership
2. Process Introduction
3. Case Evaluation
4. CO_2 Footprint
5. Applications
6. Summary

Joining forces for the development of a unique catalyst for dry reforming: a long-term journey

Ideation

R&D leads

Partnering with aknowledged R&D institute and universities

DECHEMA FORSCHUNGSINSTITUT
KIT Karlsruhe Institute of Technology
hte
UNIVERSITÄT LEIPZIG
Bundesministerium für Wirtschaft und Energie

Funded by BMBF under: 03ET1282 & 0327856

Joint Development

Lab phase	Mini plant	Pilot	Commercial
High-throughput experiments	Lab and miniplant testing	Piloting in Linde Pilot Reformer	

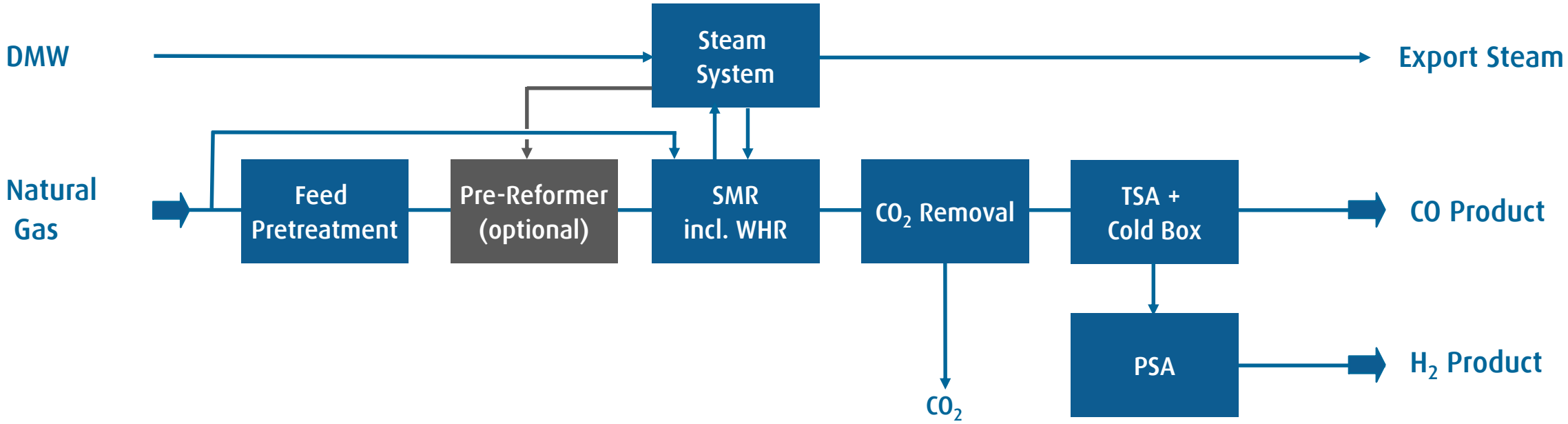
First commercial reference in industrial Linde HyCO unit 08/2017-07/2018
Full product utilization

Agenda.

1. BASF & LINDE: Innovation through partnership
2. Process Introduction
3. Case Evaluation
4. CO_2 Footprint
5. Applications
6. Summary

Process Introduction
Simplified process arrangement

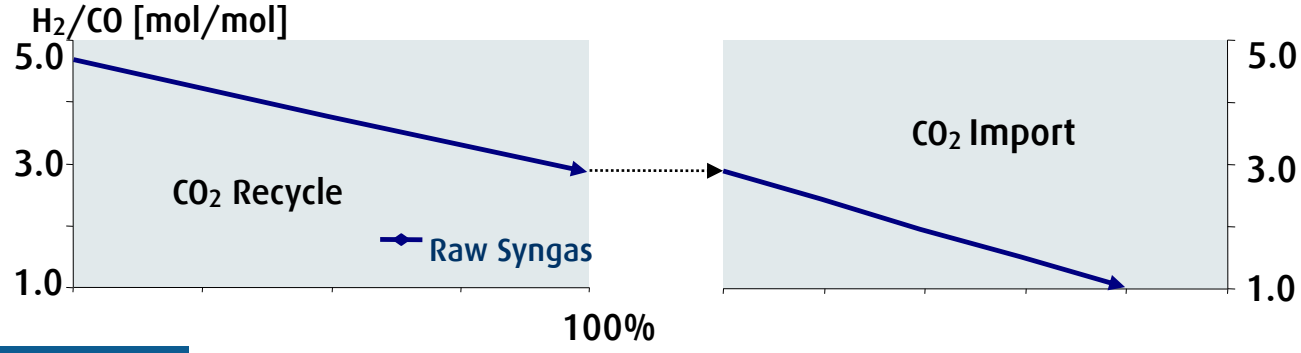
- Simplified typical process arrangement based on natural gas as feedstock and Steam Methane Reforming (SMR)
- Pre-reformer as optional equipment
- H_2/CO product ratio as target

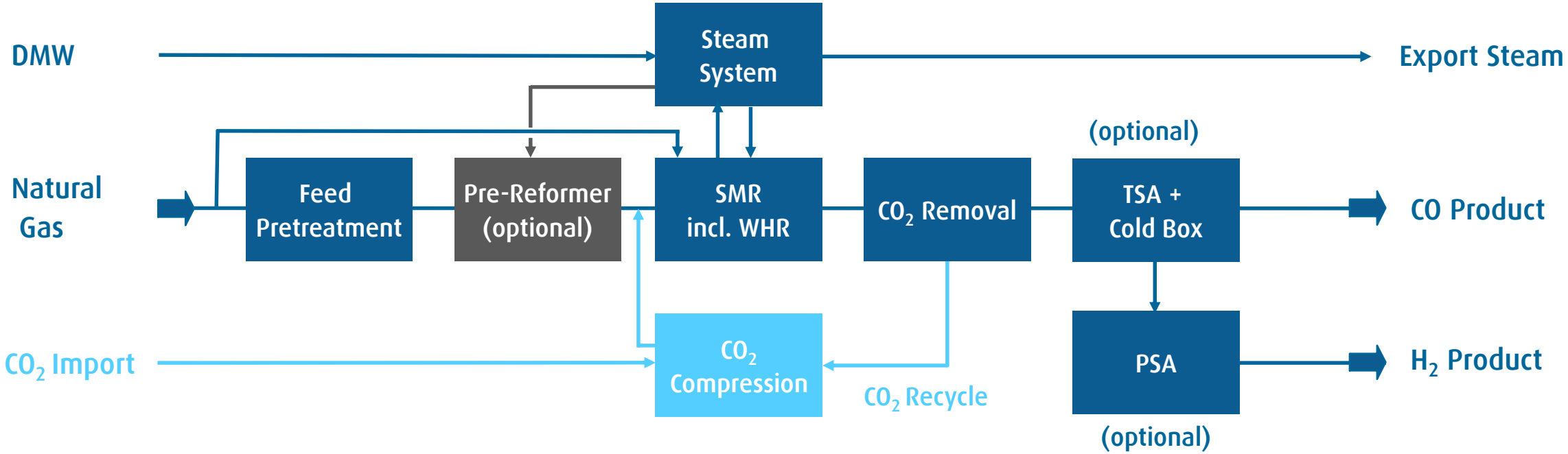


Process Introduction
CO_2 recycle and CO_2 import

How to adjust H2/CO ratio in syngas?

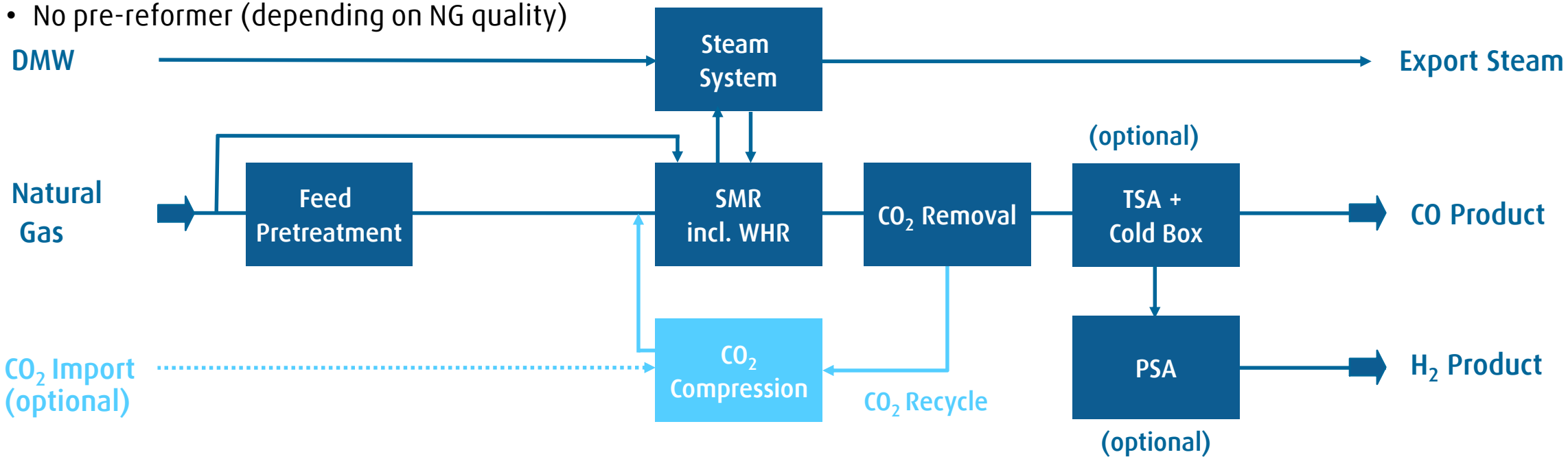
- CO_2 recycle for reduction of H_2/CO ratio
- CO_2 import for full flexibility of H_2/CO product ratio





Process Introduction
DRYREF™ process arrangement

- Application:
  - DRYREF process is typically used for natural gas based H_2+CO plants
  - CO_2 recycle to SMR with optional additional CO_2 import
- Key advantages:
  - DRYREF catalyst allows lower S/C ratio which improves OPEX and energy efficiency
  - No pre-reformer (depending on NG quality)



Agenda.

1. BASF & LINDE: Innovation through partnership
2. Process Introduction
3. Case Evaluation
4. CO_2 Footprint
5. Applications
6. Summary

Case Evaluation

Scenario 1 – without CO_2 import

Conventional process

- Steam to process: S/C 2.5 mol/mol
- Full CO_2 recycle
- No additional equipment

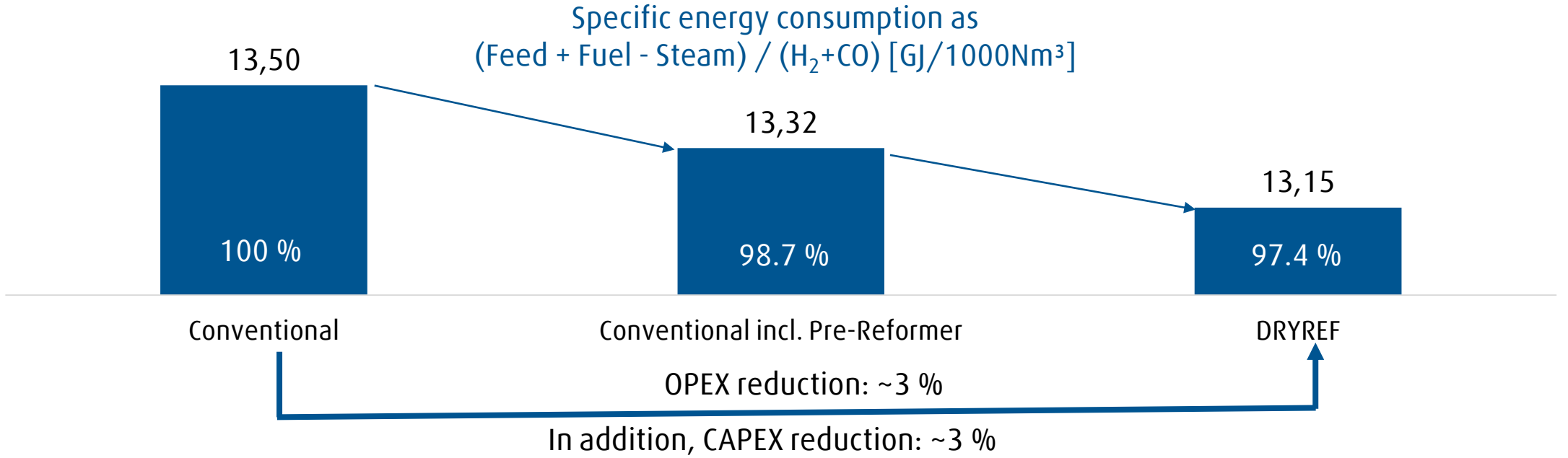
Conventional process incl. Pre-Reformer

- Steam to process: S/C 2.0 mol/mol
- Full CO_2 recycle
- Additional equipment: Pre-Reformer

DRYREF process

- Steam to process: S/C 1.5 mol/mol
- Full CO_2 recycle
- BASF catalyst (SYNSPIRE™ G1-110)
- No additional equipment

Conditions are resulting in H_2/CO product ratio of 2.45 mol/mol



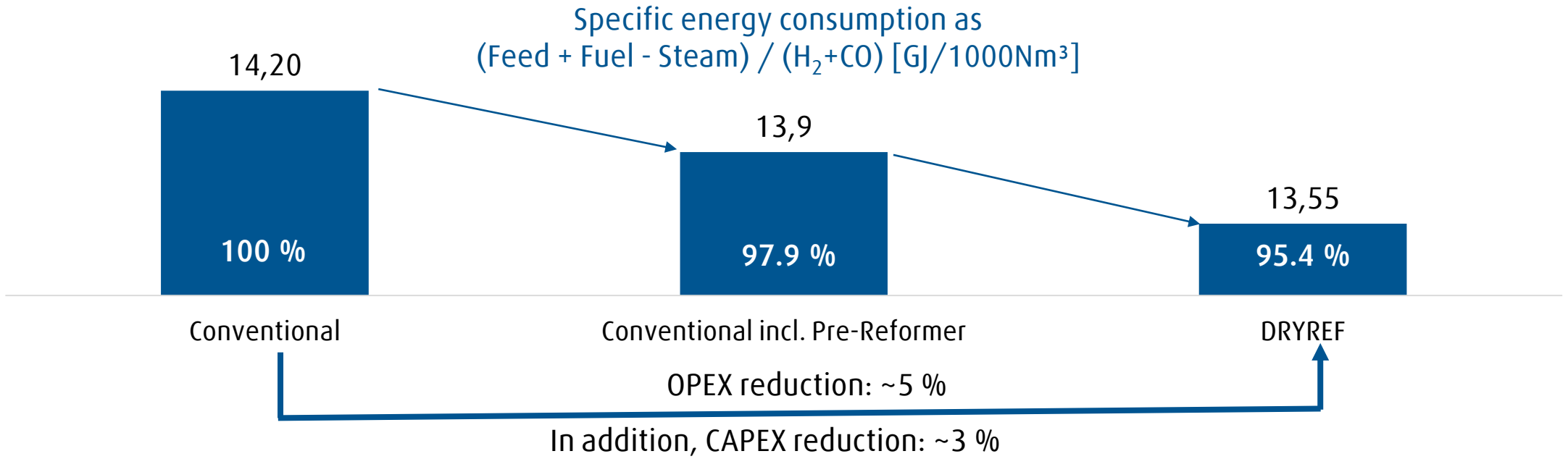
Case Evaluation
Scenario 2 – including CO_2 import

Conventional process
- Steam to process: S/C 2.5 mol/mol
- Full CO_2 recycle + CO_2 import
- No additional equipment

Conventional process incl. Pre-Reformer
- Steam to process: S/C 2.0 mol/mol
- Full CO_2 recycle + CO_2 import
- Additional equipment: Pre-Reformer

DRYREF process
- Steam to process: S/C 1.5 mol/mol
- Full CO_2 recycle + CO_2 import
- BASF catalyst (SYNSPIRE™ G1-110)
- No additional equipment

H_2/CO product ratio of 1.5 mol/mol adjusted by CO_2 Import

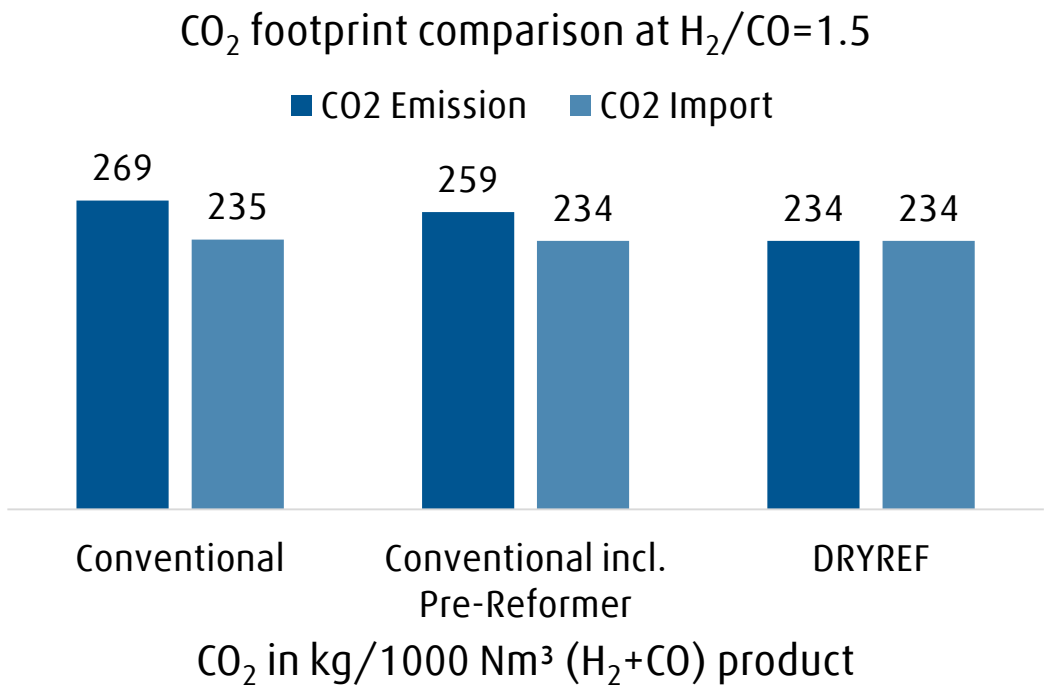


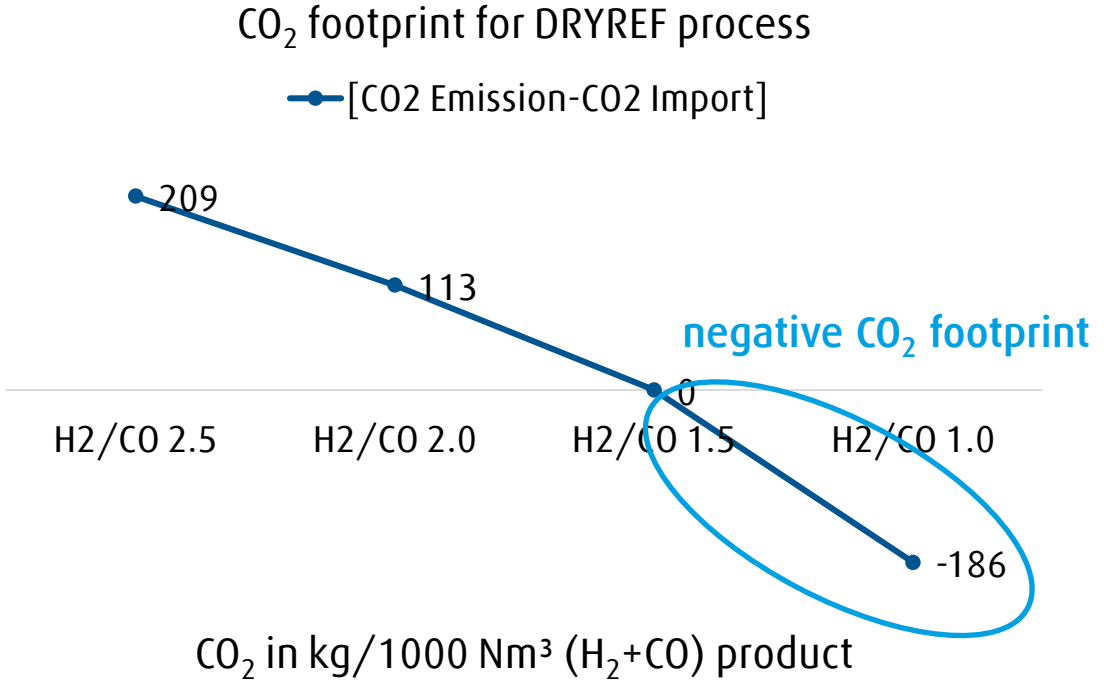
Agenda.

1. BASF & LINDE: Innovation through partnership
2. Process Introduction
3. Case Evaluation
4. CO_2 Footprint
5. Applications
6. Summary

CO_2 Footprint
DRYREF as CO_2 consuming process

- CO_2 Import is used to compensate direct CO_2 emissions from reformer flue gas
- Plant design for high air preheat temperature and minimum steam production
- Break-even to negative CO_2 emissions for DRYREF at H_2/CO product ratio of 1.5 (molar basis)



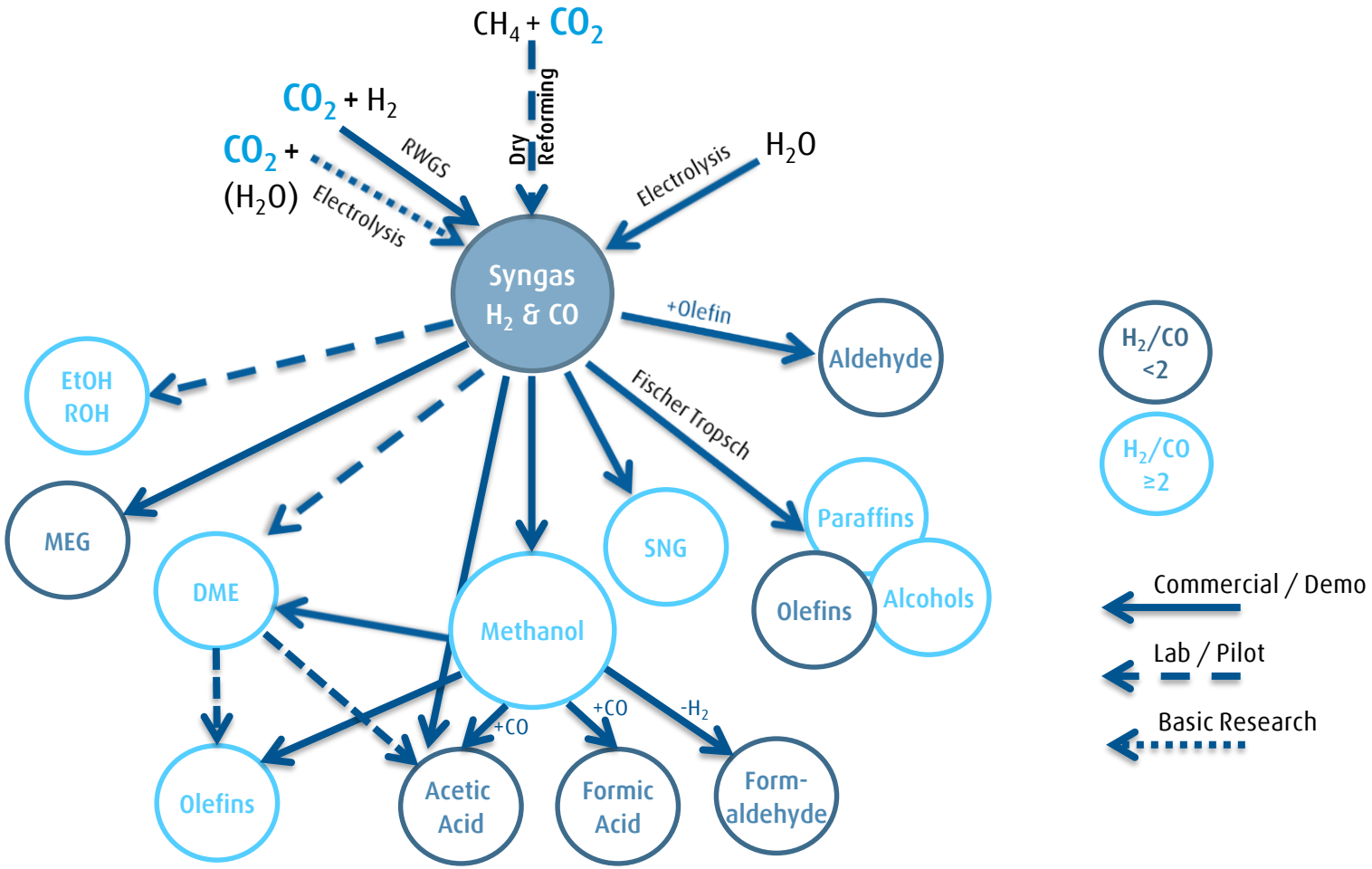


Agenda.

1. BASF & LINDE: Innovation through partnership
2. Process Introduction
3. Case Evaluation
4. CO_2 Footprint
5. Applications
6. Summary

Applications
DRYREF advantages can be obtained in many applications

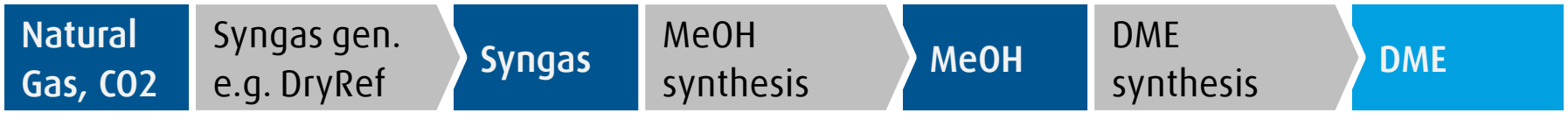
- Most syngas downstream processes require SN=2 or below
- Hence, efficiency gain by DryRef can be obtained for almost all downstream process integrations compared to conventional SMR
- Applications such as acetic acid, formic acid production, MEG and hydroformylation to aldehydes have overall H2/CO demand of 1
- Hence, these downstream needs can be addressed with negative CO2 footprint – already now!



Applications
DRYREF in combination with Direct DME Synthesis

Reference process

Conventional two step route to DME



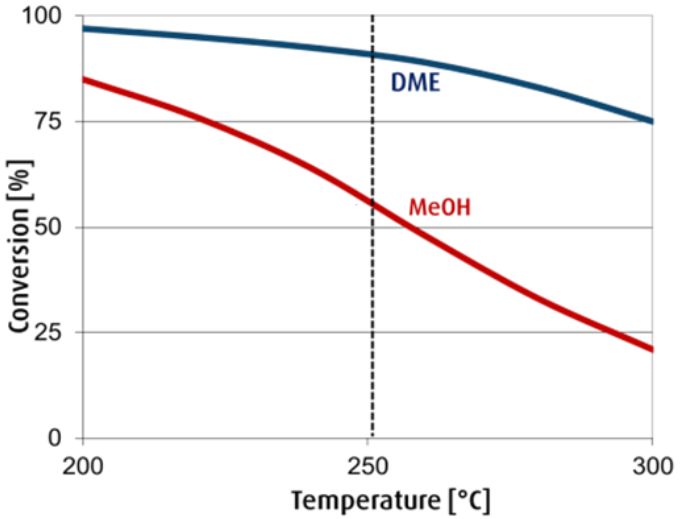
→ **Conventional DME** production requires **two steps** from syngas including **MeOH** synthesis **limited by thermodynamics**

Linde-BASF Direct DME

→ **Linde-BASF Direct DME** technology **eliminates one process step** and takes **advantage of favourable thermodynamics** for DME synthesis

→ **Specific catalyst developed on-purpose**

→ **Many process configurations** possible, **CO2 rich recycle from DME synthesis favors** DryRef with Direct DME as best process option for small and medium scale plants



optional

Agenda.

1. BASF & LINDE: Innovation through partnership
2. Process Introduction
3. Case Evaluation
4. CO_2 Footprint
5. Applications
6. Summary

Summary
DRYREF Process

Summary

- DRYREF process is typically used for natural gas based H_2+CO plants
- BASF catalyst (SYNSPIRE™ G1-110) offers possibility for operation at low S/C ratio without pre-reforming
- Energy Efficiency and OPEX is highly beneficial compared to conventional process arrangements
- CAPEX is highly competitive for new built plants
- CO_2 footprint is beneficial compared to conventional process
- CO_2 footprint is getting negative at H_2/CO product ratios below 1.5 mol/mol and minimum steam production

Outlook

- Each project is different. Linde will provide optimized tailor-made solution for your individual scenario.
- Further fields of DRYREF application:
  - Revamp projects or direct refill (customized scenarios)
  - Efficient production of H2 with low S/C ratio
  - Even lower OPEX and/or CO2 emissions for next generation catalyst DRYREF™ SYNSPIRE G2-120 in case of low H2/CO ratio

Joining forces for the development of a unique catalyst for dry reforming:
where are we on our journey?

DryRef Nickel catalyst used for HyCO1
DRYREF™ SYNSPIRE G1-110

DryRef Cobalt catalyst for LPR
DRYREF™ SYNSPIRE G2-120

Joint Development

	Lab phase	Mini plant	Pilot	Commercial
SYNSPIRE G1-110	High-throughput experiments	Lab and miniplant testing	Piloting in Linde Pilot Reformer	First commercial reference Linde HyCO unit 08/2017-07/2018, full product utilization open for commercial 3rd party projects
SYNSPIRE G2-120			Piloting in Linde Pilot Reformer successfully finished 10/2020	Demonstration: open for partnering

contact Linde Engineering: (1) DRYREF feasibility of your project, (2) demonstration of G2-120, or (3) LPR test campaigns!

Thank you for your attention.

Linde Engineering
Andreas Peschel
Tel +49 89 7445-4296
andreas.peschel@linde.com
www.linde.com

Making our world more productive