From Petroleum Refinery to Biomass Refinery

German-Russian Forum Biotechnology 2011
Hannover, 10th October 2011 at the Biotechnica

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German-Russian Forum Biotechnology 2011
Agenda

Linde Engineering Dresden GmbH – Part of the Linde Group

— Competence Center BIOTECHNOLOGY and seat of Linde's global product line biotechnology plants

Linde Involvement the Implementation of Industrial Biotechnology

— Process development and scale-up facility "CBP Leuna"

From TODAY's Chemical Sites to FUTURE Integrated Sites – Example LEUNA

— Ethylene from biogenic feedstocks

— Hydrogen from liquid biogenic sources

Outlook & Summary

Linde Engineering Dresden GmbH is an Integral Part of The Linde Group

The Linde Group

Sales: 12.9 Billion EUR (2010)
Employees: > 50 000

Gases Division

Leading supplier of industrial gases

Engineering Division

Engineering & contracting specialist

Linde Engineering Dresden

- Chemical, polymer and gas plants
- Biotech & pharma plants

Other Activities

Gist logistics solutions
Cleaning Enterprises

Integration is "Key to Success" for Industrial Biotech/Biorefinery

Linde Engineering Dresden - Overview

Linde Engineering in Dresden, Germany
Office in Moscow, Russia

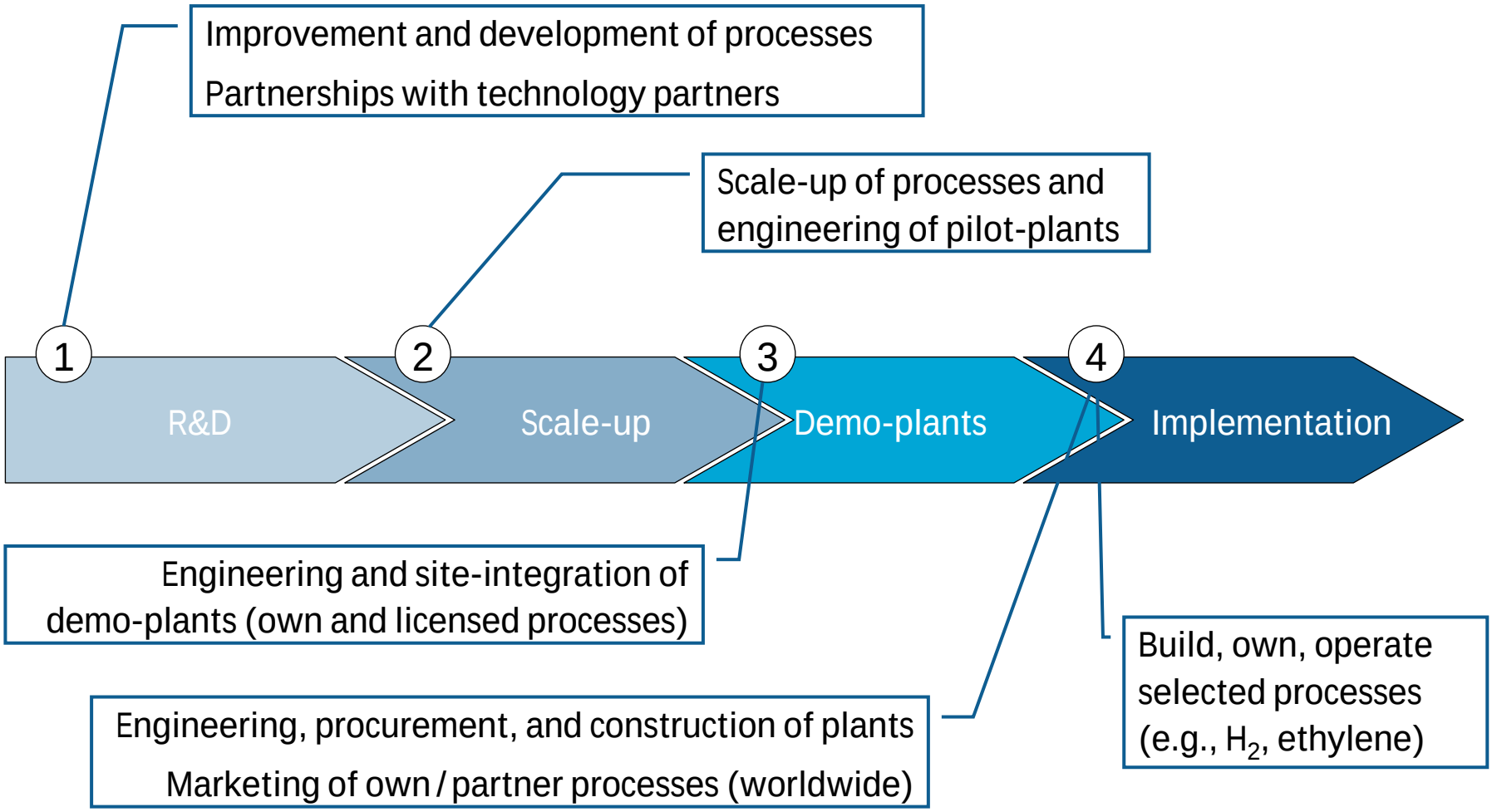
- **Global responsibility for biotechnology**
- Global responsibility for carbon & energy solutions
- Polymer and chemical plant expert
- Center of excellence for the Russian market
- Flexible and innovative EPC contractor

Sales 2010: approx. 250 million €, Employees: approx. 500

Linde Engineering Dresden – Biotechnology Plants

- **Industrial (White) Biotechnology**
  - Biorefineries
  - Intermediate chemicals
  - Starch
  - 2G Biofuels
  - Biopolymers
  - Enzymes
  - Algae
  - Food additives
- **Pharmaceutical (Red) Biotechnology**
  - Active pharmaceutical ingredients
  - Insulin
  - Pharmaceutical finished dosage forms
  - Fractionation of blood plasma

Linde involvement the Implementation of Industrial Biotechnology



Scale-up Facilities are of Critical Importance

R&D

— Promising processes
— Start-ups involved
— Selected steps only
— Little integration

CBP – Fraunhofer center for the development of chemical- and biotechnological processes

CBP Leuna

— No scale-up facilities / or no access to
— High investment in own facilities
— Risk of IP-loss in competitor facility

— Nucleus of Biorefinery-activities
— Integrative process research
— Global process optimization
— Sustainable processes

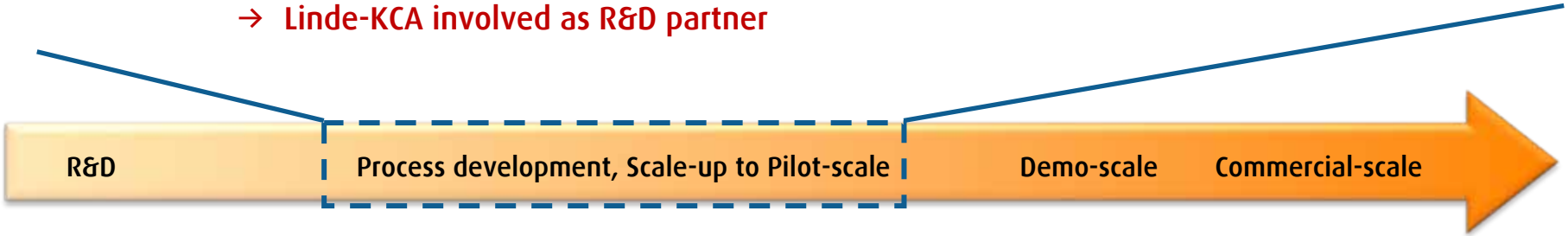
Implem-entation

Fraunhofer Center for the Development of Chemical/Biotechnological Processes – CBP Leuna

- > 8.000 m² total space
- 25 L to 10.000 L process volume
- USP, processing and DSP equipment
- Feedstock flexibility
- Several individual modules
- Integrated in chemical site Leuna
- Construction ongoing, start Q2 / 2012

→ Linde-KCA selected as general contractor technology in EU-wide tender

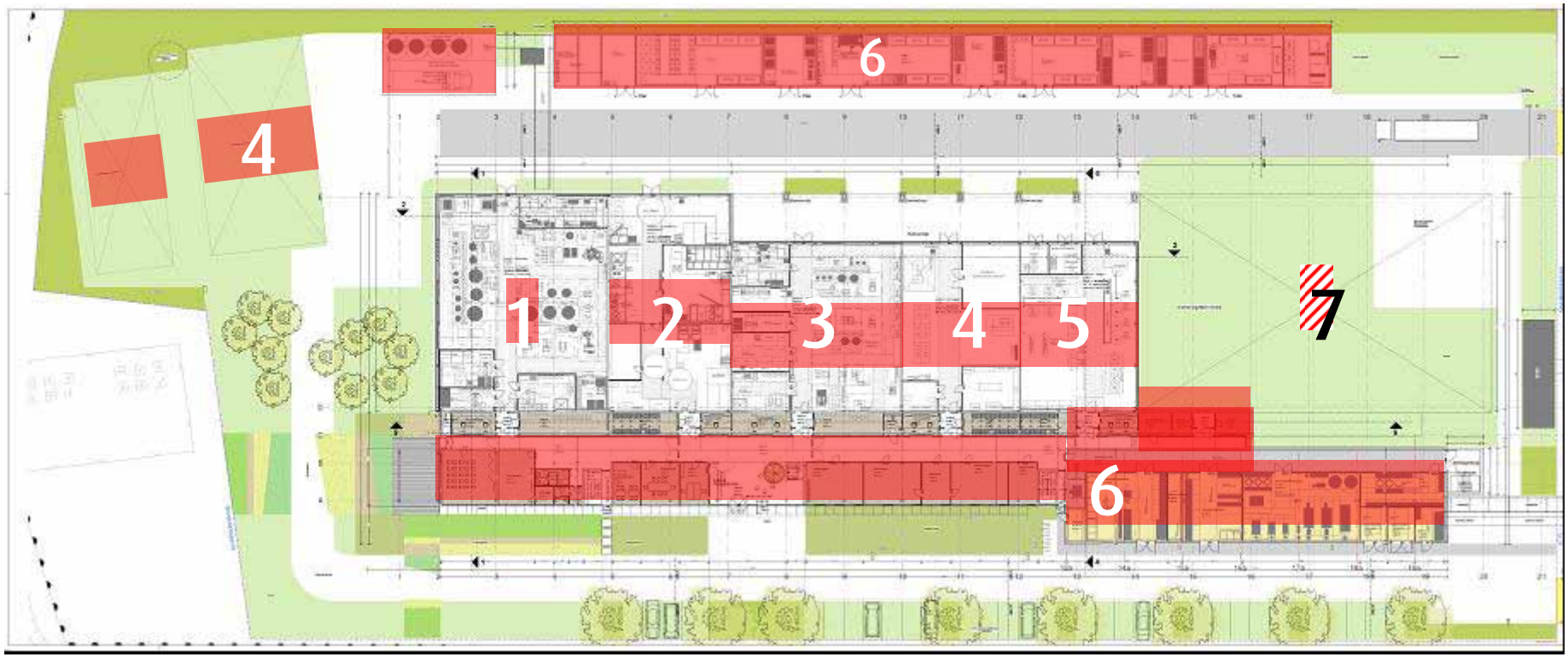
→ Linde-KCA involved as R&D partner



CBP Leuna – Construction is Under Way

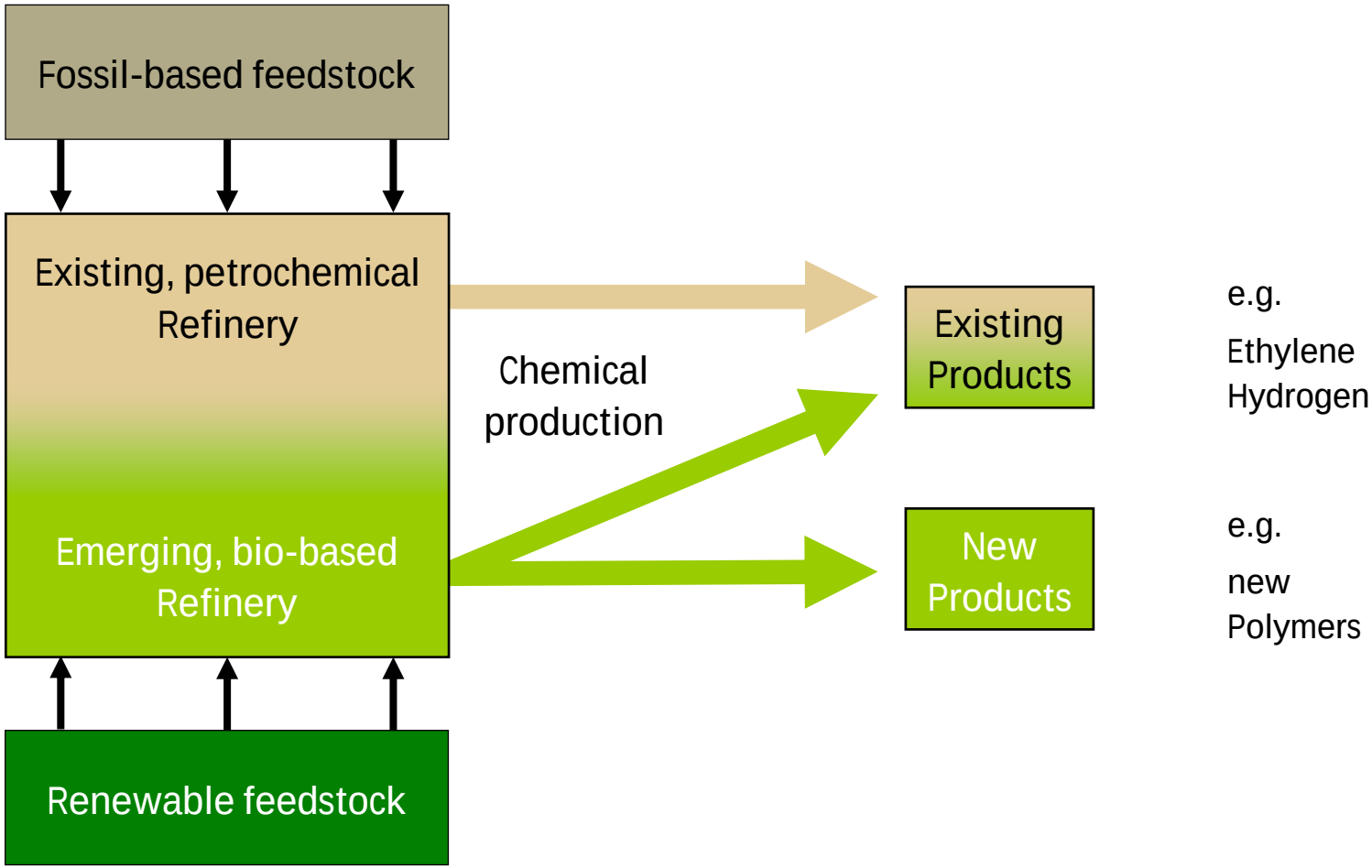
September 29, 2011

CBP Leuna
Development & Scale-up of a Wide Range of Processes



- 1: Innovative enzyme processes
- 2: Lignocellulose biorefinery
- 3: Innovative fermentation processes
- 4: Microalgae, greenhouse, downstream
- 5: Bio-Ethylene and biogas
- 6: Office, utilities and storage
- 7: Future Expansion

From TODAY's Chemical Sites to FUTURE Integrated Sites

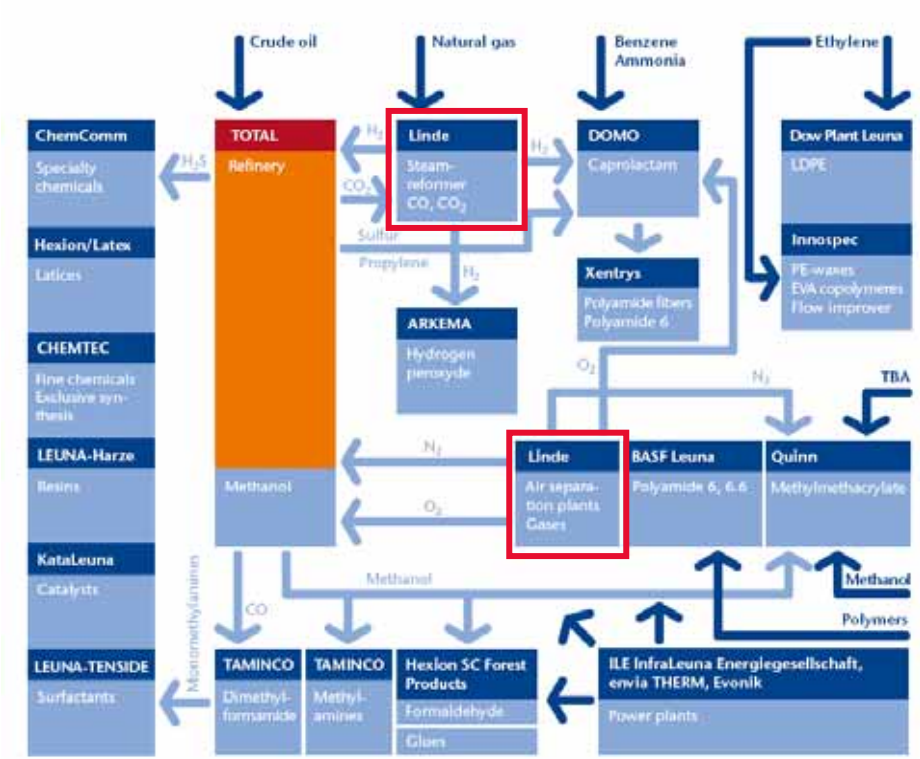


From TODAY's Chemical Sites to FUTURE Integrated Sites – Example Leuna

Leuna chemical site – refinery at night

Site internal network – companies and major feedstock/product lines

Linde Gas / Linde Gas as shareholder



Source of picture and diagram: InfraLeuna GmbH

Ethylene from Biogenic Feedstock – A Promising Example for Biomass Refineries

Mega plants

1 m t / yr Ethylene

~ 1 bn € investment

~ 1,000 € / t (pipeline)

Bio-Ethylene

5 - 100 kt / yr Ethylene

and in between?

approx. 1,400 € / t

(on-site production)

@ 30 – 50 kt / yr plant

Container & Cylinder

< 1 kt / yr Ethylene

+ liquefaction / filling (300 € / t)

+ transport (400 € / t)

~ 1,700 € / t (truck transport)

Bio-Ethylene Market – Promising Development

THE LINDE GROUP

Linde

— Customer pull (Coca-Cola, Pepsi, Heinz, Volvic, Procter & Gamble, etc.)

— Green image towards end-users

— Value-added for ethanol (first commercial plants based on 1G ethanol operating)

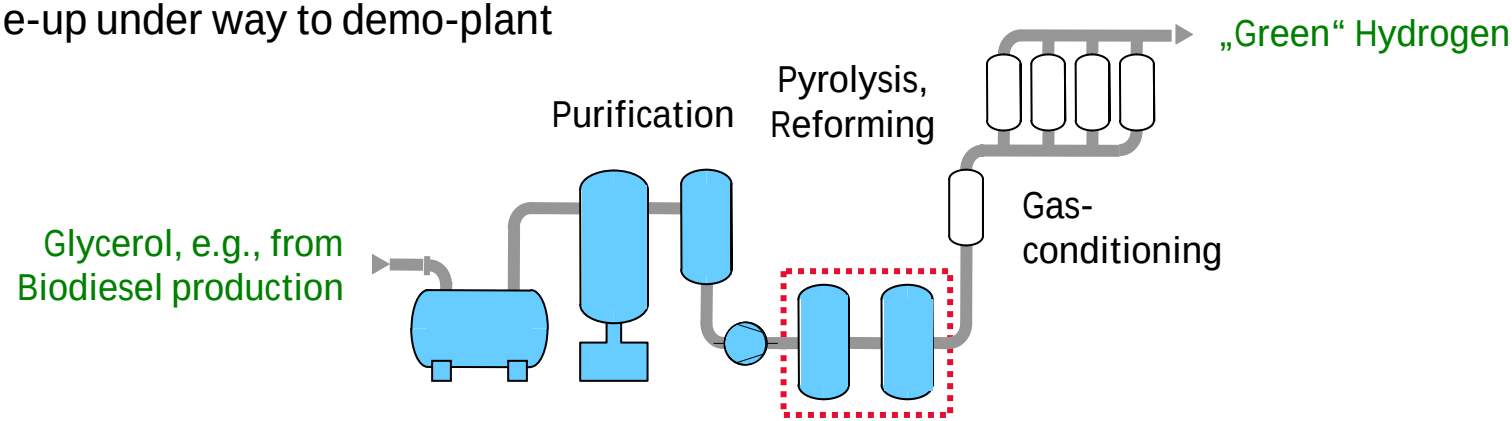
— Linde activities ongoing with Partners (medium scale, plants based on 2G ethanol)

Biobased Hydrogen – "Green" Reactant for Biorefineries
New Linde Pilot Plant in Leuna

THE LINDE GROUP

Linde

- Cost-competitive technology to produce biogenic hydrogen via pyro-reforming of glycerol
- Takes advantage of existing Linde technologies
- Other biogenic feedstocks possible (tests ongoing)
- Successful start-up of pilot plant Q2 / 2010
- Capacity approx. 400.000 Nm^3 / year
- Approx. 140 kg H_2 / t Glycerol
- Sustainable CO_2-footprint
- Scale-up under way to demo-plant



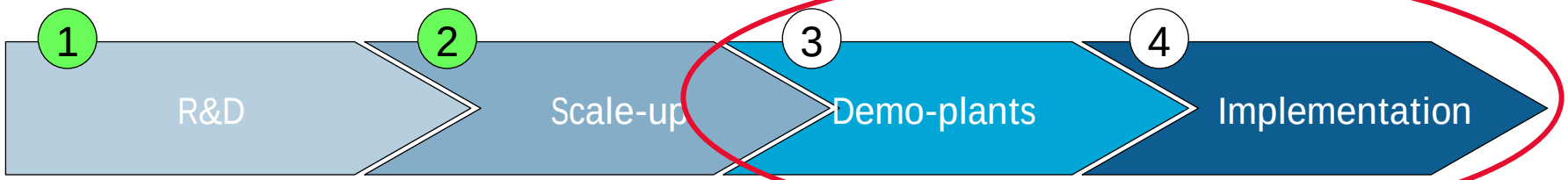
Hydrogen to Glycerol Pilot Unit in Leuna

Next Steps Towards Bio-based Chemicals

Development, improvement of processes

- Industrial collaborations
- Collaborations with universities, Fraunhofer
- Government funded projects (national / international)

Ongoing activities with partners

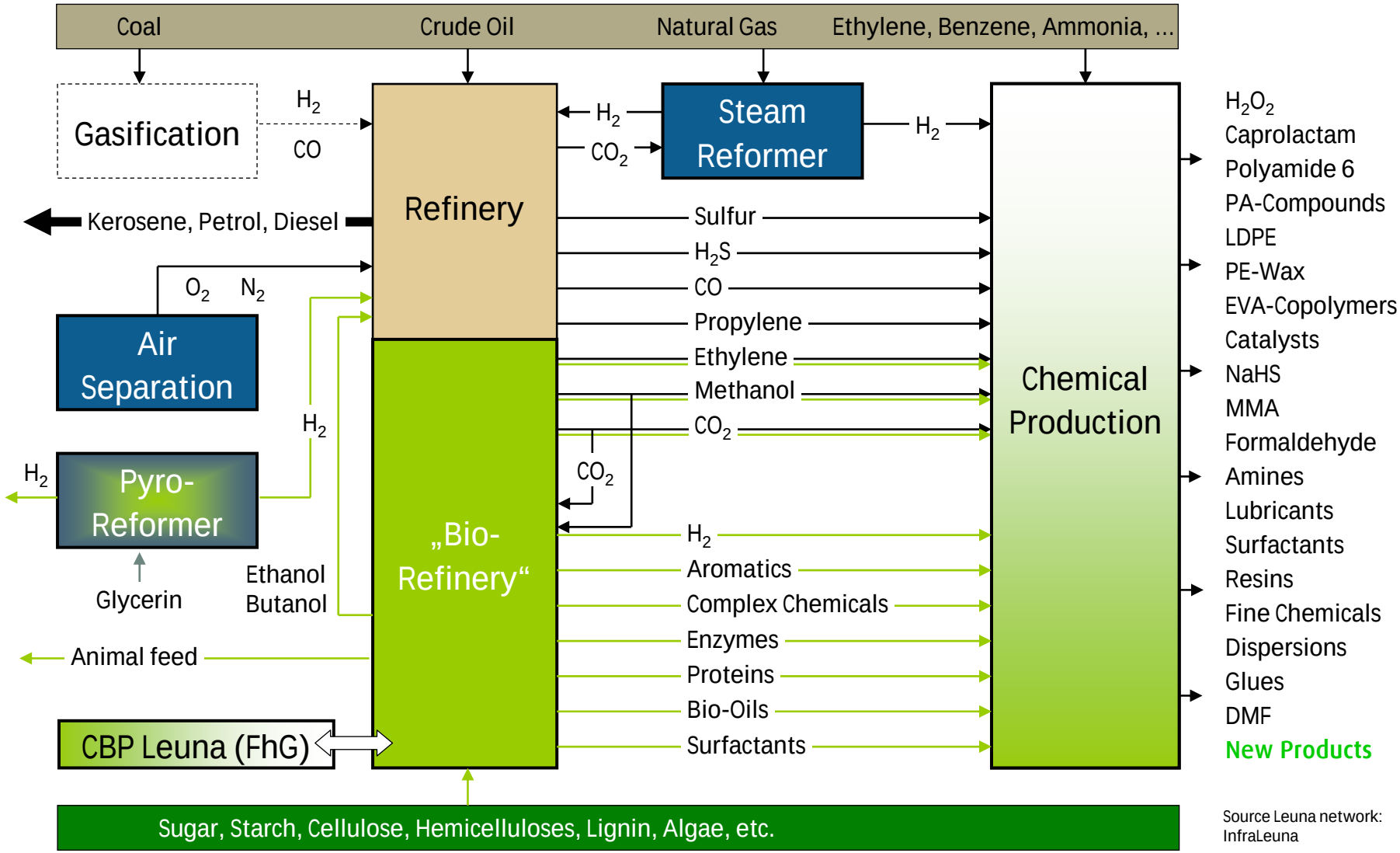


Scale-up of processes from lab to pilot scale

- General contractor and partner of Fraunhofer CBP*
- Linde pilot plants

* Center for the development of chemical- and biotechnological processes - CBP

Outlook „Biorefinery Leuna“ – Model for an Integrative Site Concept



Source Leuna network: InfraLeuna

Summary
Linde's Position and Interest in Industrial Biotechnology

- **Industrial Biotechnology is one of our key-development fields**

- **As global competence center, Linde Engineering Dresden**
  - is leading the industrial biotech activities for the Linde Group
  - owns or has access to innovative process technologies (strategic partnerships in place)
  - has extensive experience in the design and construction of plants at all scales

- **Linde Engineering Dresden is interested in collaborations along the renewable value-chain, e.g., in the fields of**
  - non-food feedstocks, agricultural products or residues
  - innovative biotechnological / chemical processes
  - joint marketing approaches
  - EPC of plants in the industrial biotech field, e.g., lignocellulosic-based gases and chemicals, starch-plants, etc.

Thank you for your attention.

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