From fossil- to bio-based refineries.

Stepwise implementation of integrative plant concepts.

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Agenda

The Linde Group

— Linde-KCA-Dresden GmbH – competence center BIOTECHNOLOGY

From fossil- to bio-based refineries

— Key drivers

— Status and development trends

— From TODAY'S bio-based production to FUTURE integrated Biorefineries

Vision "Biorefinery Leuna"

— "Bioethylen" as an example for the integration of a bio-based value chain

— Why bioethylen?

— Future integrative scenario

Conclusion & Outlook

The Linde Group Profile

THE LINDE GROUP

The Linde Group

Sales: 12.7 billion EUR (2008)
Employees: > 50 000

Gases Division

Leading supplier
of industrial gases

Engineering Division

Engineering &
contracting specialist

Linde-KCA

- **Chemical and gas plants**
- **Biotech & pharma plants**
  competence center Linde-KCA

Other Activities

Gist logistics solutions
Cleaning Enterprises

Linde-KCA – Competence center BIOTECHNOLOGY „white/industrial“ & „red/biopharma“

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Synergistic cooperation of divisions — Integration of biotechnology & chemistry

Biotechnology Plants (B)

- Biotechnology
  - process technology
  - basic know-how
- design & construction of large-scale biotech plants
- process technology fine chemistry

Chemical and Gas Plants (C)

- Chemistry
  - process technology
  - basic know-how
  - own and licensed processes
- design & construction of large-scale chemical plants

„key to success“ for BIOREFINERY projects

Selected reference BIOPHARMA – Large-scale cell culture plant for production of MABs

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Client
F. Hoffmann-La Roche AG

Location
Basle/Switzerland

Type of plant
New cell culture plant for production of monoclonal antibodies (MAB)

Investment
400 mio CHF

Product
Anticancer drug Avastin

Scope of work
Project coordination, Conceptual design, Basic engineering, Detail engineering, Support in procurement, Engineering support during installation and commissioning

Commissioning
2007

Selected reference INDUSTRIAL BIOTECH – Starch-based first generation biorefinery

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Client
FRP CS GmbH

Location
Zeitz / Germany

Type of plant
Plant for production of
modified wheat starch and gluten

Scope of work
Conceptual design,
General contractor technology *)
(Engineering, Procurement,
Construction, Commissioning)

Planning period
2006 – 2009

*) in consortium with firm Kaefer Construction GmbH
as general contractor building

Selected reference REFINERY – Linear alpha olefin plant

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Client & development partner
United Petrochemical Company

Location
United Olefins Complex in Al-Jubail/Saudi Arabia

Process
Sabic Linde "α-Sablin" Process

Capacity
150 000 t/a α-Olefine

Process steps
Feedstock and catalyst handling, reaction and catalyst removal, primary separation, product separation

Scope of work
Turnkey lump sum: Detail engineering, procurement, construction, precommissioning, commissioning support

Start-up
2006

Selected reference CHEMISTRY – Polyethylene plant

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Client
Eastern Petrochemical Company (SHARQ)

Location
Al-Jubail/Saudi Arabia

Process
PE process licensed by SABIC

Capacity
800 000 t/a HDPE and LLDPE

Process Section
Raw material purification, catalyst preparation, polymerization, additive handling, pelleting, vent recovery, pellet blending and storage, bagging and palletizing, bulk loading

Scope of work
Turnkey lump sum

Start-up
2009 (planned)

From fossil- to bio-based refineries – Key drivers

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Feedstock change – trend to renewable raw materials

- securing supply in view of the looming shortage of fossil feedstocks
- rising costs of fossil feedstocks
- autonomy of supply

Sustainability

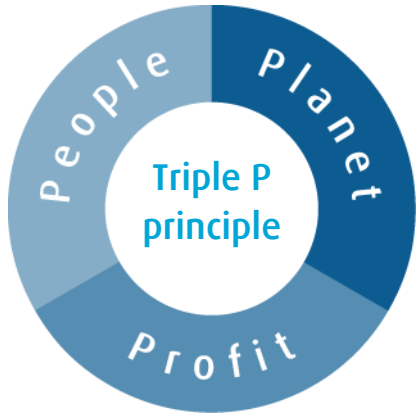
- neutral/positive C02-balance
- with respect to energy, water, resources, environmental burdon

Political will

- to establish a bio-based economy in Europe
- to keep Europe in a leading position in White Biotech
- to support European agriculture

Economics

- new/innovative products
- cheaper production processes



From fossil- to bio-based refineries – Status & development trends

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Use of renewable raw materials TODAY

A 1G biorefineries
(e.g. bioethanol, starch, pulp & paper)

Source: Press photo Südzucker

B (petro)chemical sites with individual biotech plants

Source: Press photo BASF

FUTURE trends

2nd/next generation biorefineries

fully integrated biotechnological and chemical production sites

From TODAY'S 1G bio-based refineries to FUTURE Biorefineries

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A

new integrative plant concept

expansion of raw material basis → LC biomass

improve efficiency

improve sustainability

expansion of product range → chemical intermediates

Expansion of the raw material basis – Strategic alliance Linde/Süd-Chemie for 2G Biofuel plants

SÜD-CHEMIE
Creating Performance Technology

Linde Engineering

Süd-Chemie:

- biocatalyst and process supplier
- process know-how lab-scale
- process know-how demo-scale

Linde:

- engineering all scales
- construction all scales
- know-how unit operations

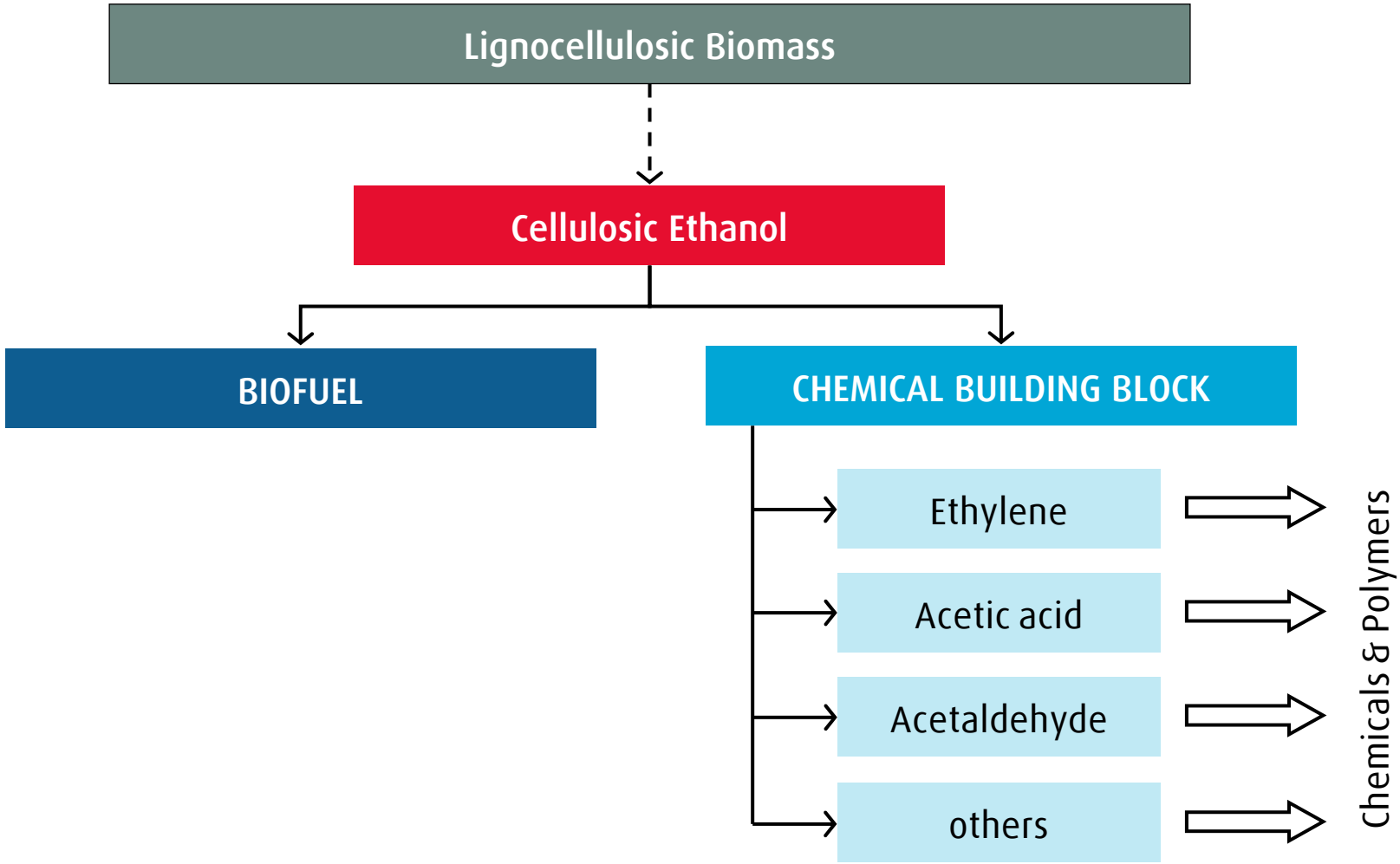
Target:

Development and construction of Cellulosic Bioethanol plants

Optimised biocatalysts and processes from SC are the key for economical process and low production cost

Linde as global acting design company ensures efficient transfer in large scale plant

Expansion of the product range – Ethanol as building block for chemical intermediates



From TODAY's chemical sites to FUTURE integrated bio/chem sites – Leuna as an example

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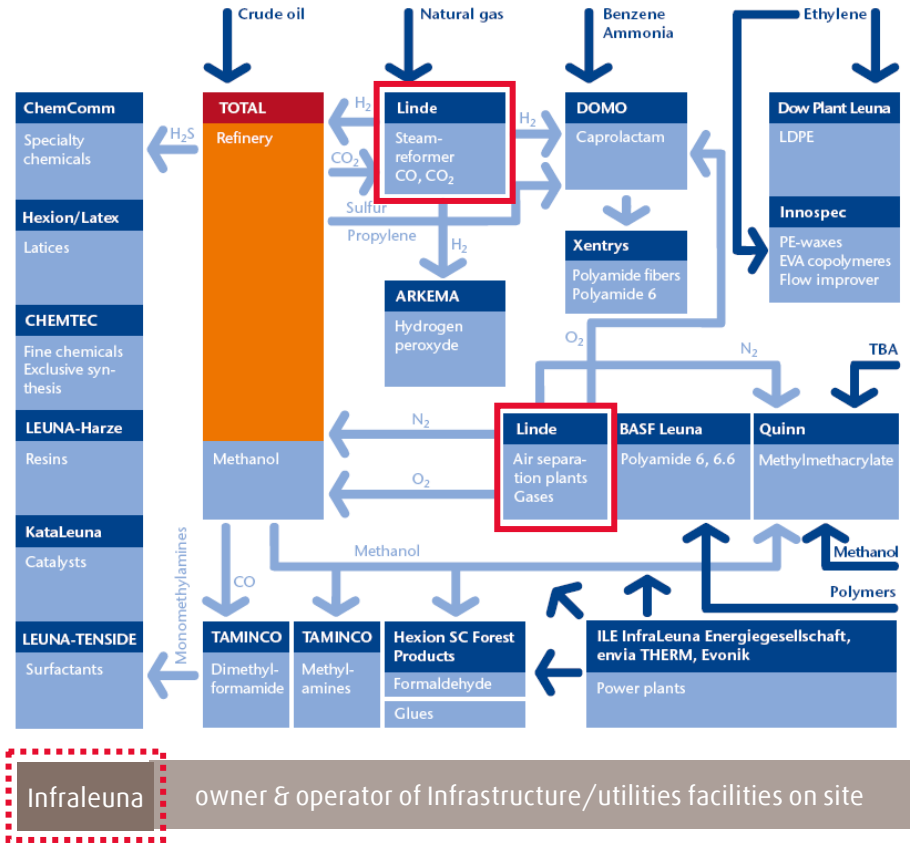
B Leuna chemical site – Refinery at night

Site internal network – companies and major feedstock/product lines

Linde Gas/Linde Gas shareholder



Source of picture and diagram: Infraleuna

Leuna chemical site – infrastructure & service on site

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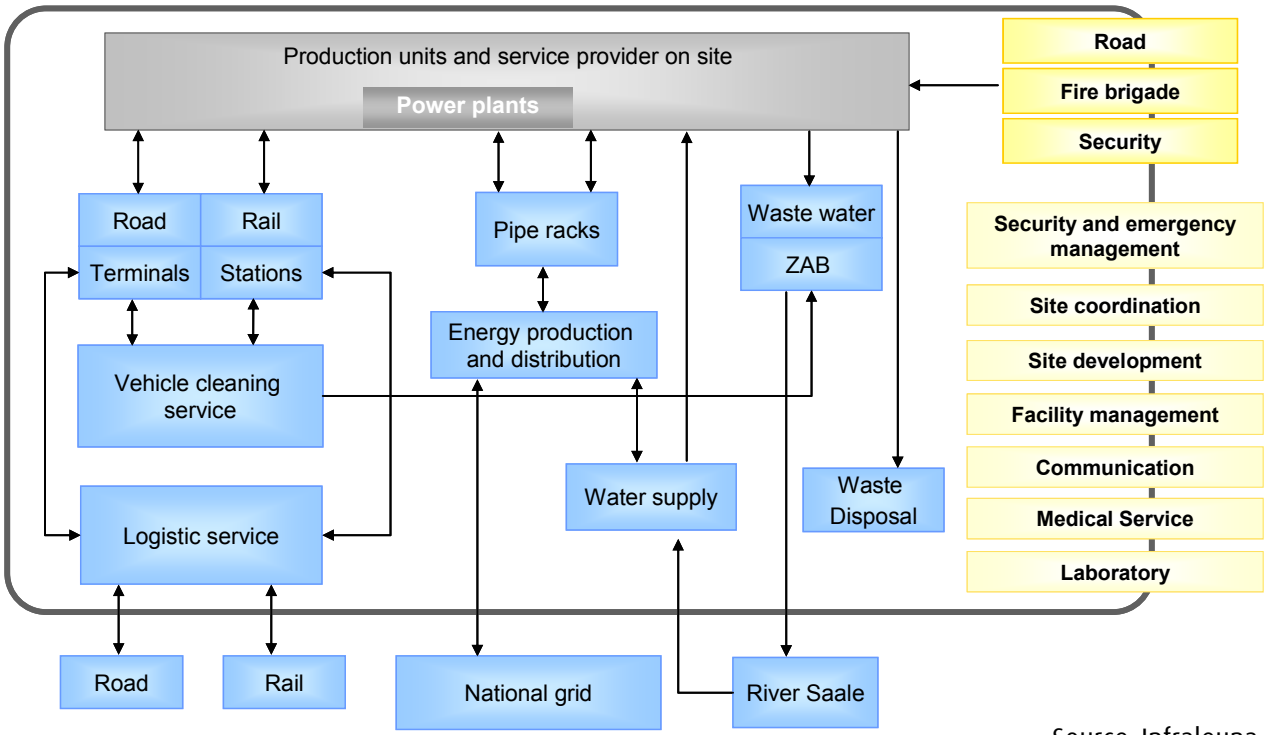
Advantage for bio-based processes upon integration:

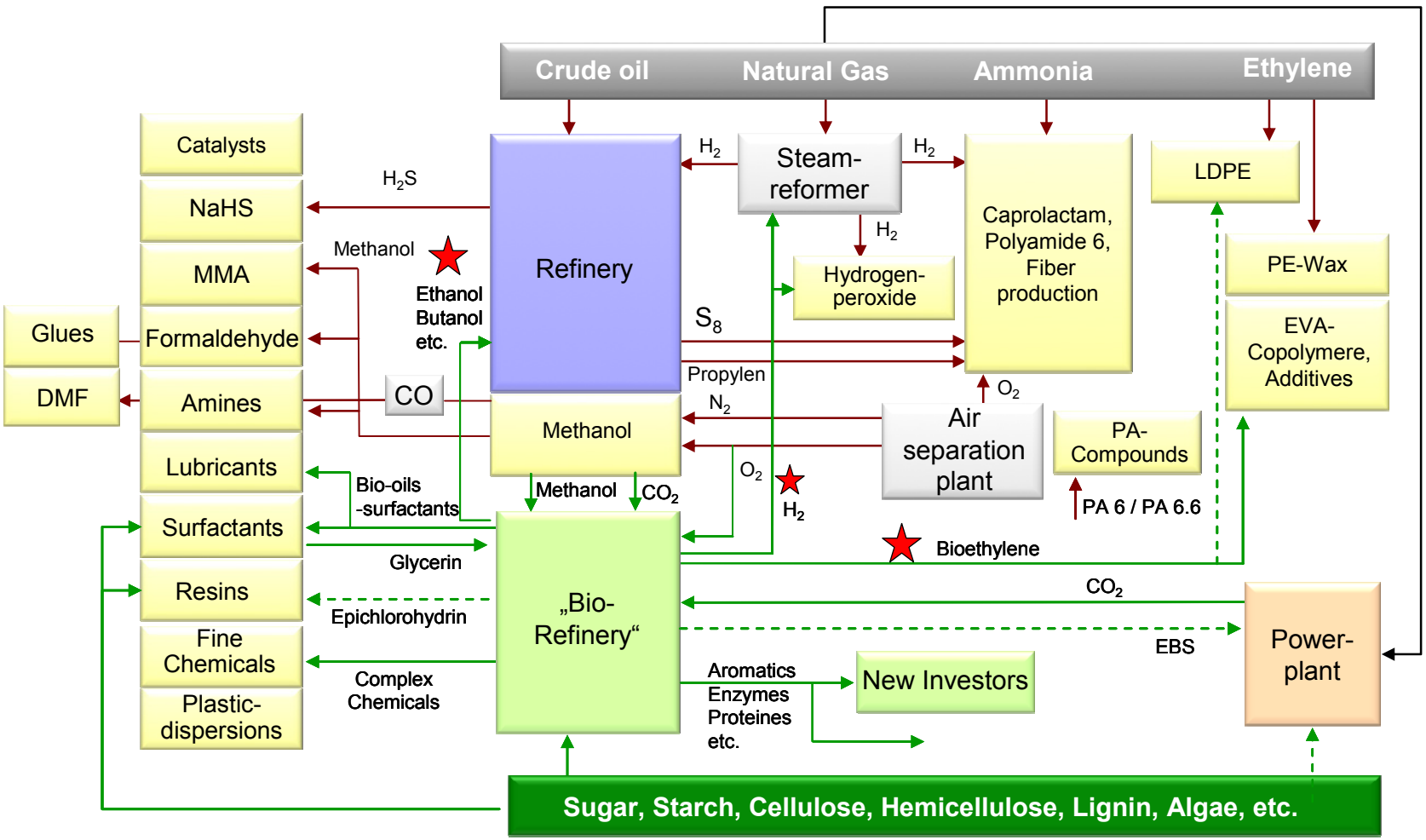
- use of existing site facilities (infrastructure, utilities, services)
- integrated energy concept
- support in approval processes



cheaper than greenfield investment!

Source: Infraleuna

Vision „Biorefinery Leuna“



Source: InfraLeuna

Ethylene market – a heterogenous business with potential for renewable raw mateials

Mega plants
1 m t/a ethylen
~ 1 bn € invest volume

ca. 1 000 €/t
when transported by pipeline

Bioethylen
5 000 – 100 000 t/a ethylen

... and in between?

ca. 1 200 €/t
when produced on site
with a 30-50 kta plant

Container & Cylinder
< 1 000 t/a ethylen
+ liquefaction/filling (300 €/t)
+ transport (400 €/t)

from 1 700 €/t
when transported by trucks

Bioethylen –
Alternative production routes & preferred option

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Raw Materials

lignocellulose

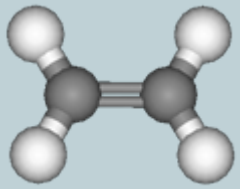
starch

sugar cane

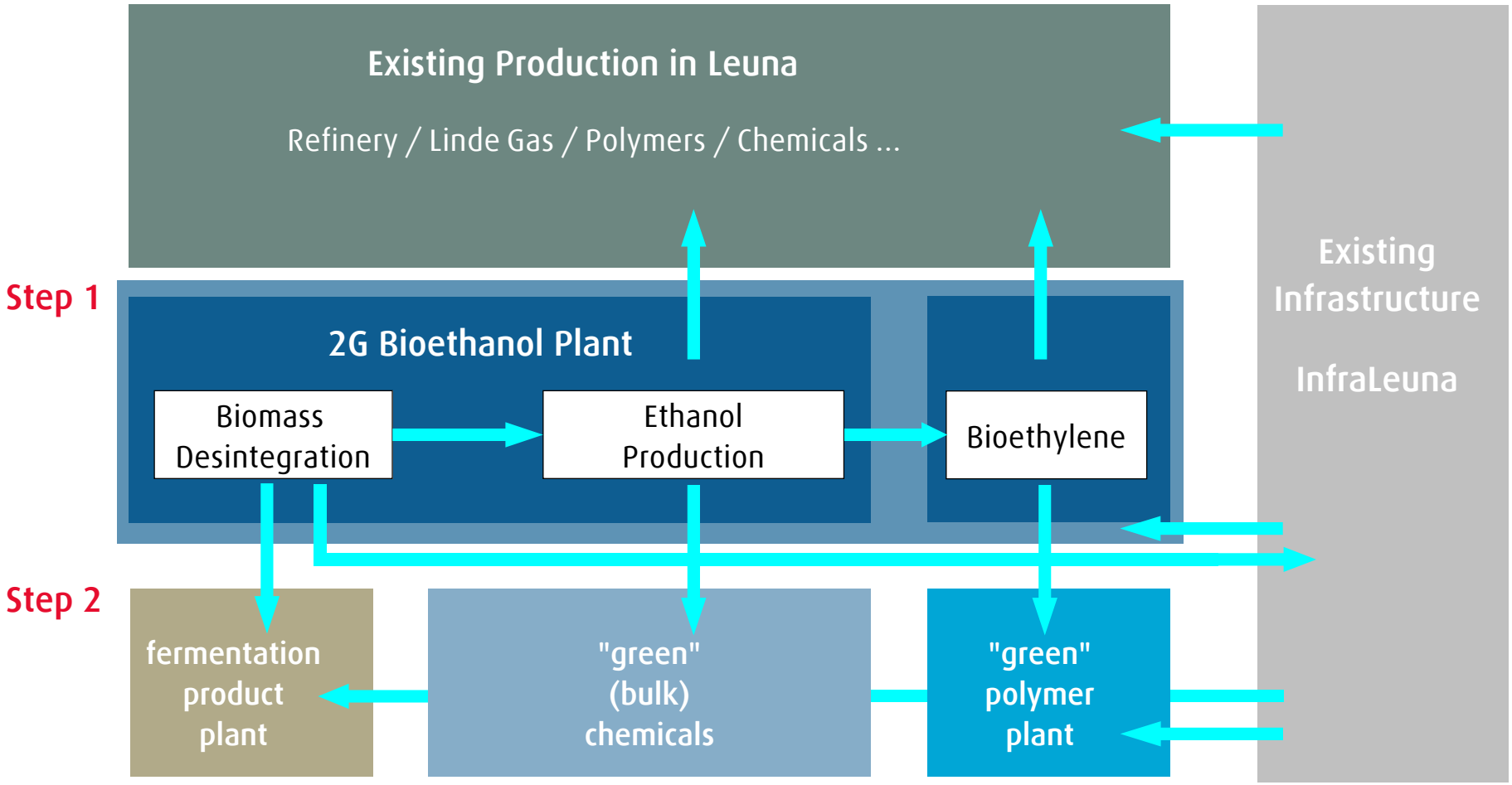
Ethanol

Source: Press Center Agrana

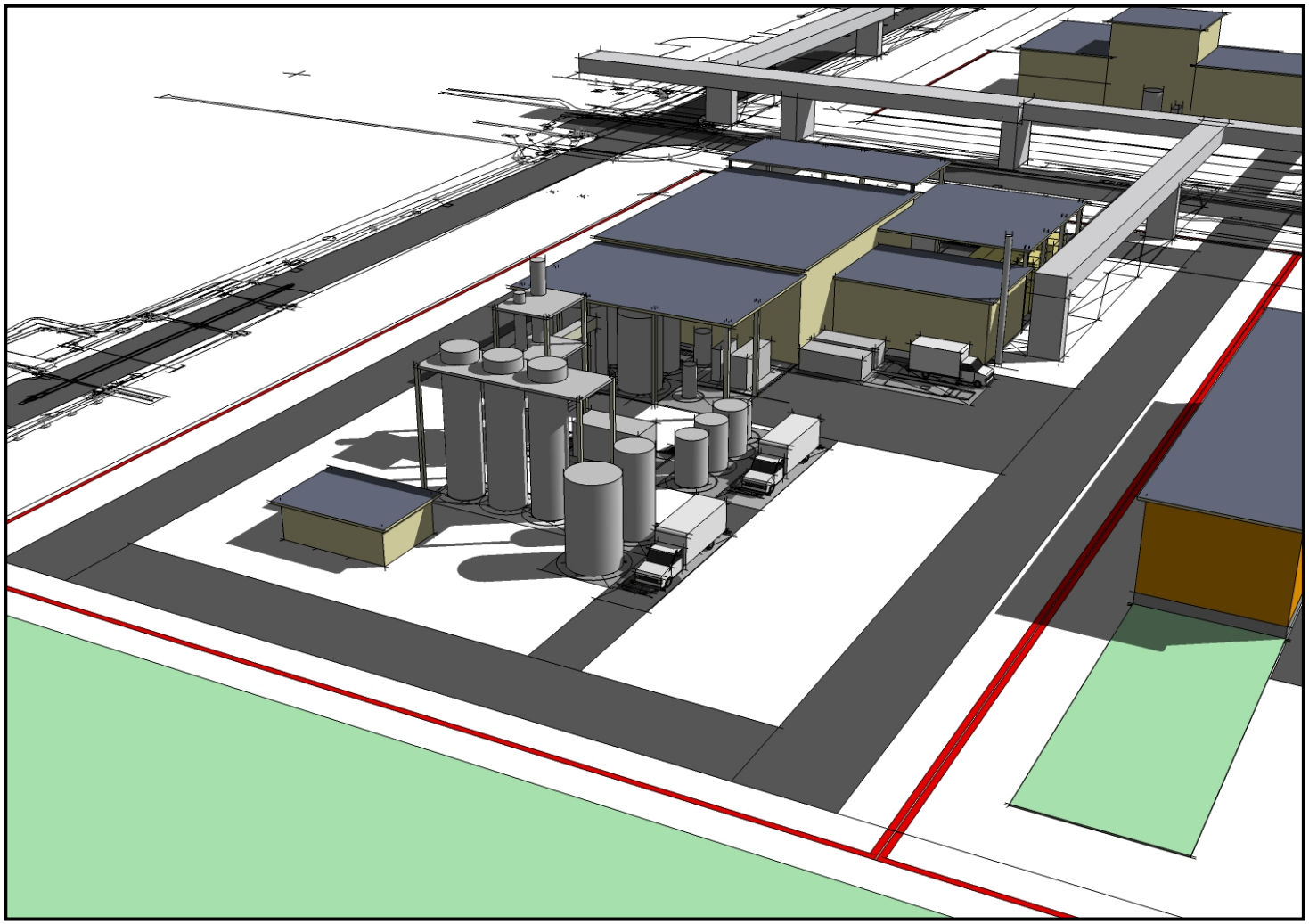
Ethylen



Biorefinery – potential future integrative scenario for e.g. Leuna with 2G bioethanol plant as central module



Integration bioethanol & bioethylen – real life scenario



Conclusion & outlook

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Future trend - from "1G reality" to integrated next generation biorefining

Challenge:

— from established mature technology with easy-to-process food & feed raw materials and well-known products

— to emerging technologies under development with difficult-to-process LCB raw materials and either established or novel products

Option:

— replacement of fossil-based refineries by new large-scale greenfield biorefineries?

Preferred short to midterm solution:

Integrative bio/chemical "Verbund" concepts tapping the full synergy potential of existing sites

Thank you for your interest.

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