IEA IETS Task 11

Industry-based biorefineries towards sustainability

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IETS Task 11 – Focus and Vision

Focus: Biorefineries integrated in industrial complexes – leading to decarbonization and energy efficiency

Interdisciplinary approach:

- industrial process technologies,
- energy efficiency
- biomass conversion and cascading use

Picture: KI based image creation, https://huggingface.co/spaces/stabilityai/stable-diffusion

Vision:

- Energy and resource efficient Biorefineries – new products, new pathways, possibly integrated to industrial complexes
- Biorefinery concepts with net zero / negative emissions

IEA IETS Task 11 Industrial Biorefineries towards Sustainability

International Consortium: Austria, Finnland, Schweden, Canada and Portugal

Austrian Consortium:

AEE INTEC

Energieinstitut an der JKU Linz

TU WIEN, Institut für Verfahrenstechnik, Umwelttechnik und Technische Biowissenschaften

SUBTASK 1: Decision Support System and Ex-Ante Research – criteria to evaluate strategies

SUBTASK 2: Net-zero/Negative emission biorefineries - concepts for integrated biorefineries to reach net-zero/negative emissions

Source: AEE INTEC

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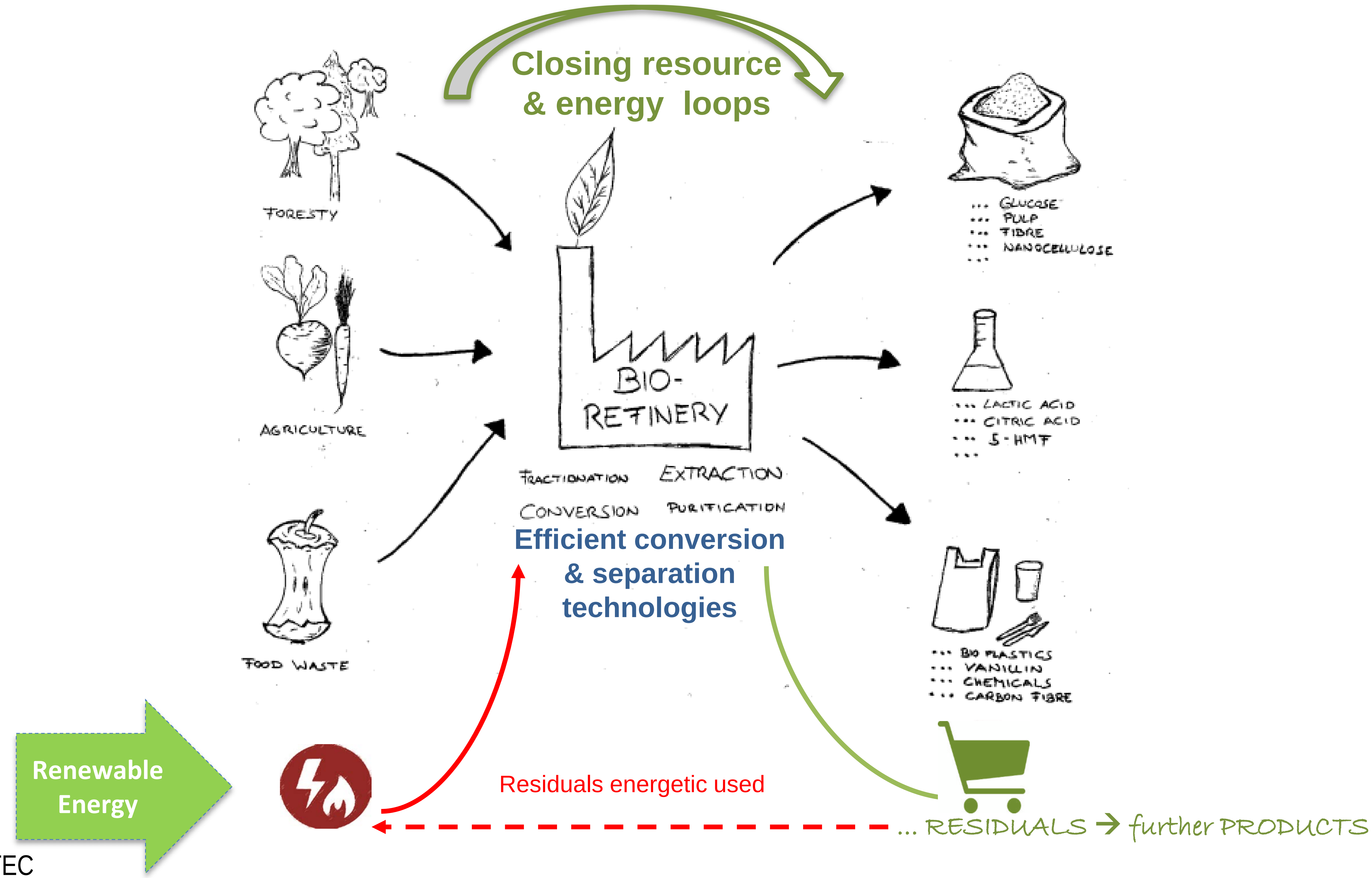
Optimized Biorefinery



Source: AEE INTEC

SUBTASK 1: Decision Support System and Ex-Ante Research

Higher focus on resource use for material products, lower energy generation potential, can require energy in processing, utilities, chemicals etc.

Are resource and energy efficiency contradictory?

- Decision support systems (DSS) are available:
  - Advantages for integrating a biorefining technology
  - Technical impact
  - Scenarios of being economical and ecological

- **Weak points of DSS**: combined consideration of energy and resource efficiency

Key performance indicator set
to evaluate energy and resource efficiency

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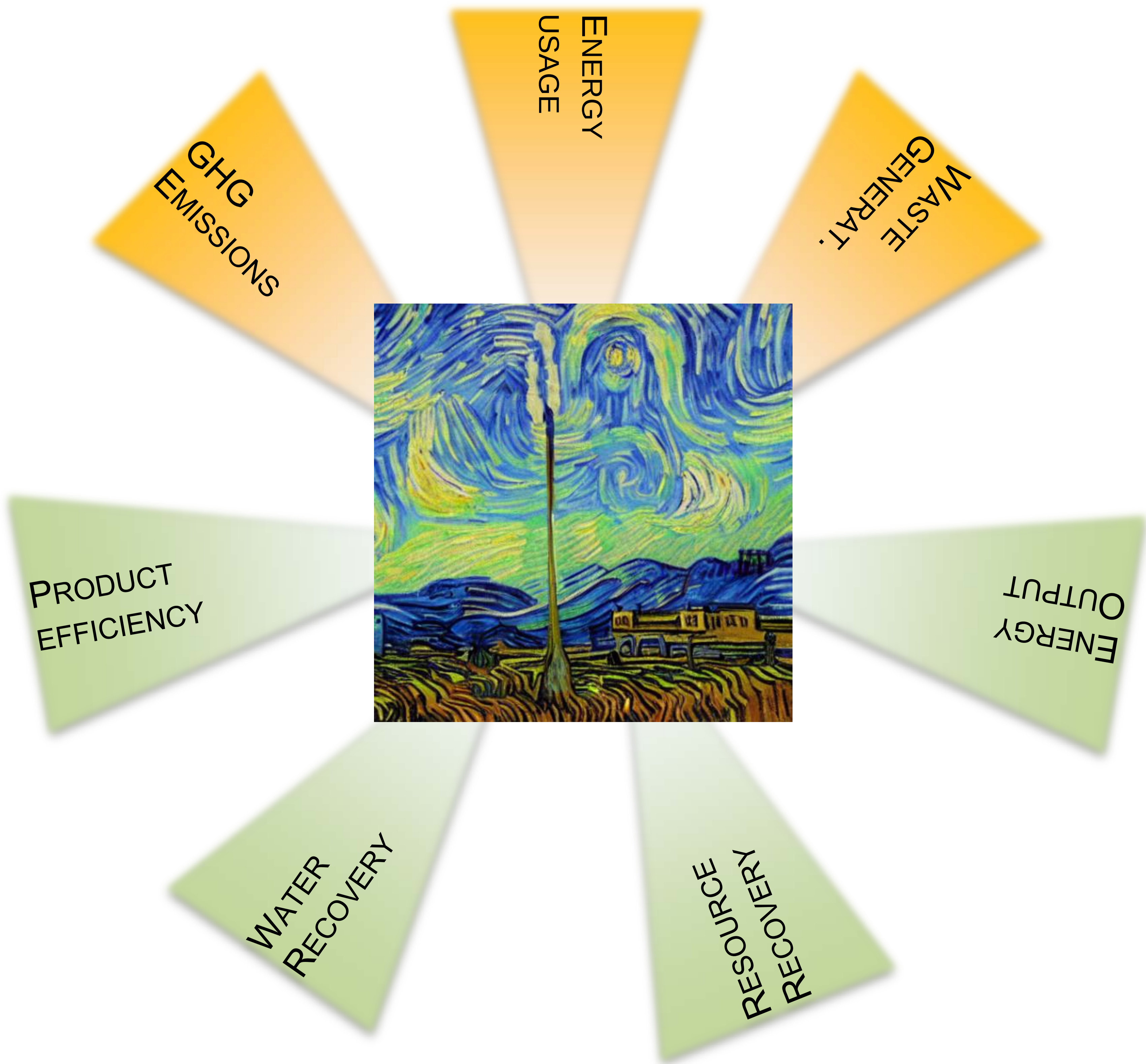
KPIs - Dimensions

Specific KPIs
for individual process steps

Global KPIs
for the entire system

Benchmark KPIs
to compare different scenarios and biorefineries with each other



KPI	Equation
Energy consumption	$\frac{kWh}{kg\ Biomass}$
Resource recovery	$\frac{kg_{Product}}{kg_{Biomass} + kg_{Additives}} * 100$
Chemical usage	$\frac{kg_{Additives}}{kg_{Product}}$
Water recovery	$\frac{m^3\ Water_{recycled}}{m^3\ Water_{fresh}} * 100$
Product efficiency	$\frac{kg_{Product}}{kg_{Biomass}} * 100$
Specific energy yield	$\frac{kWh_{Biogas}}{kg\ COD_{inlet}}$
GHG emission	$\frac{g\ CO_2\ Äq}{\mathrm{kWh}} * \frac{kW}{10^6} * operating\ hours$
Grade of waste	$\frac{kg_{Waste}}{kg_{Inlet}}$

Picture: KI based image creation, https://huggingface.co/spaces/stabilityai/stable-diffusion

CS1: WWTP - Scenarios of optimization

- **Scenario 1 & 2**
  - Integrating a **primary clarifier** with an additional **primary sludge thickener**
  - **Nutrient recovery (ammonia)** with a membrane distillation
- **Scenario 3**
  - Substitution of the primary clarifier with a **cellulose recovery system (product = wet cellulose pulp)**

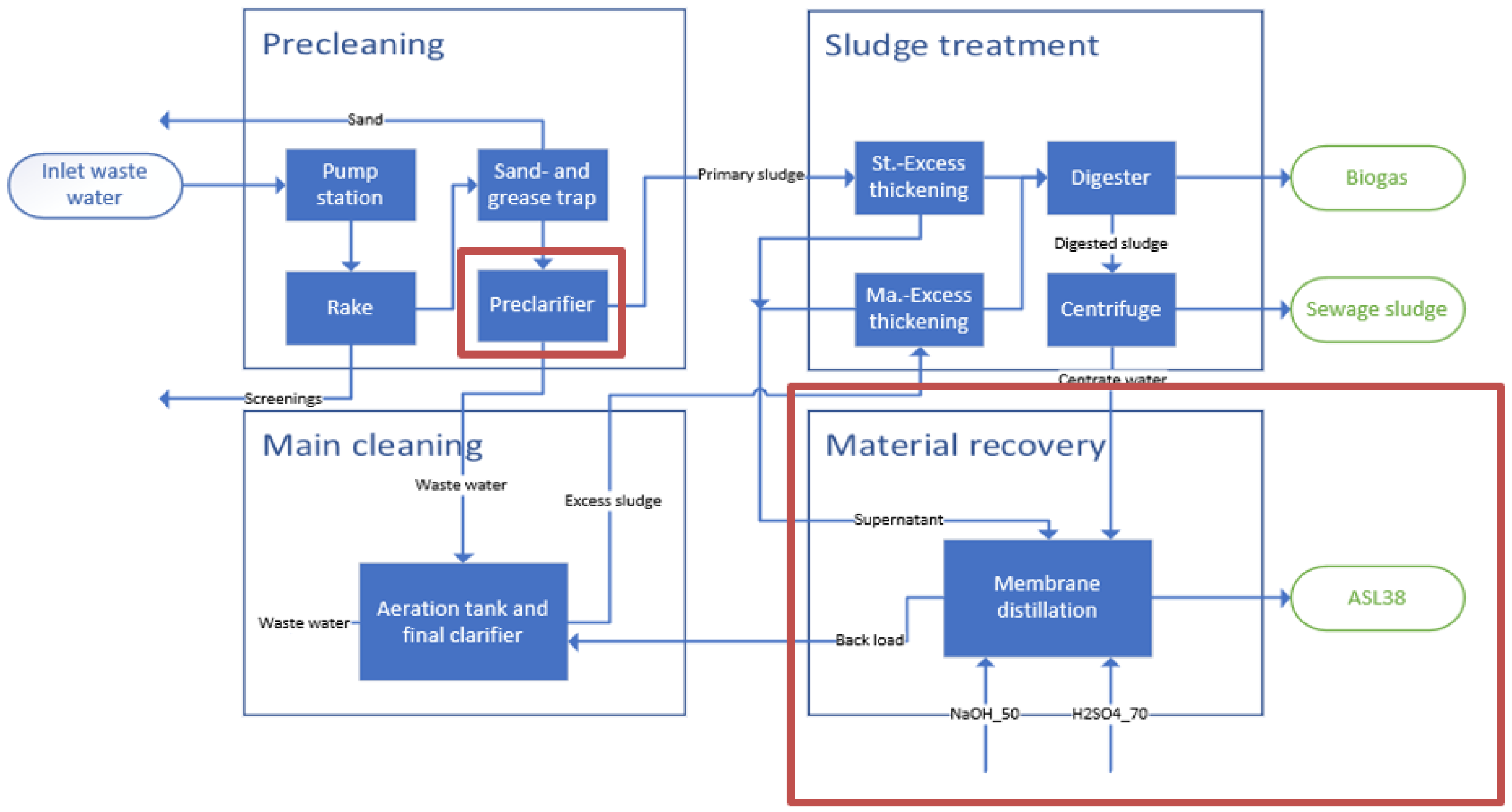


Fig.: Scenario 1 & 2

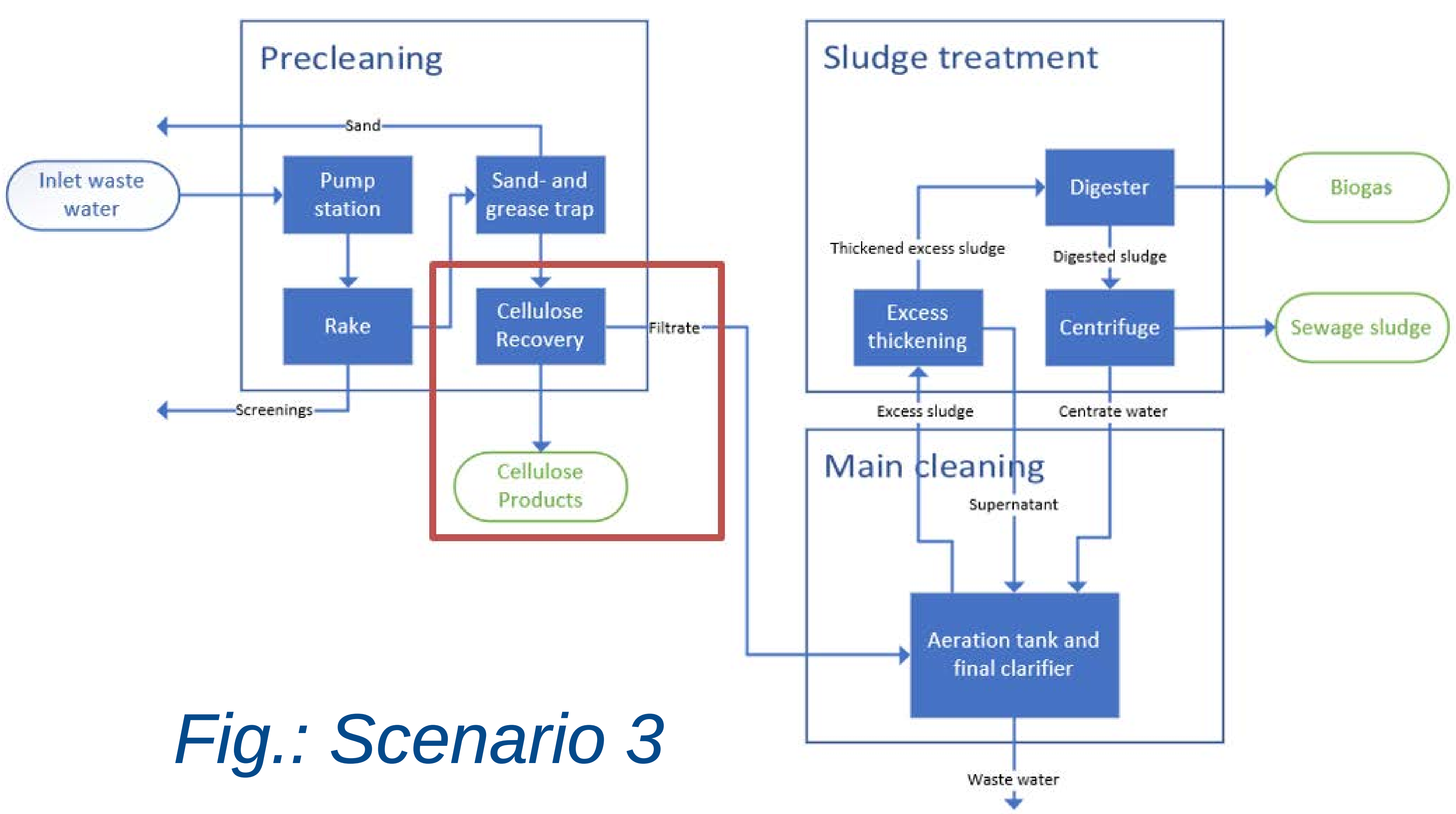
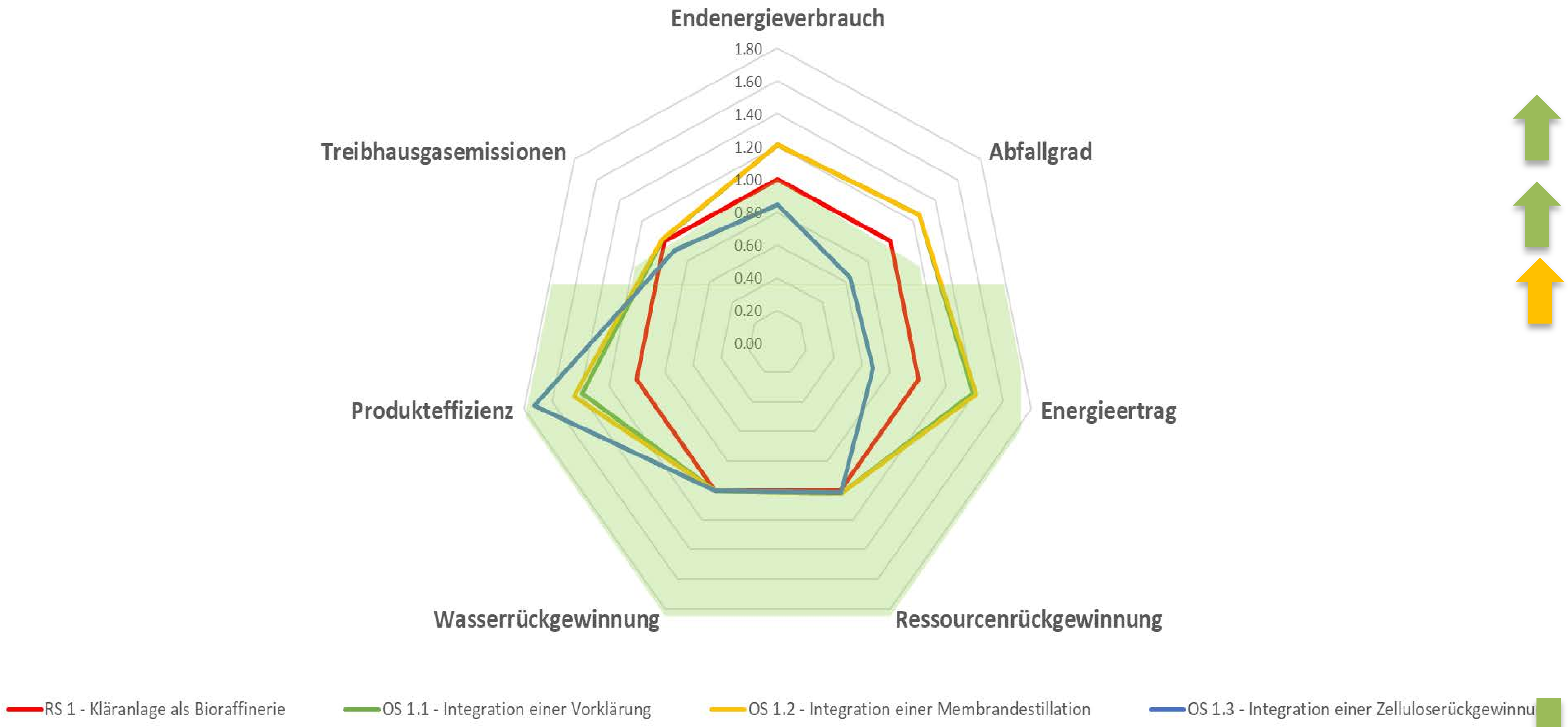


Fig.: Scenario 3

178 Mt/a NH3
Haber Bosch = 1-2% of world final energy demand; 1,44% of CO2 emissions
energy losses: 50%

75-90% of NH3 used for fertilizer production (e.g. urea, ammonia-sulfate solutions)
50% of world's food production relies on fertilizing

CS1: WWTP Results



Source: AEE INTEC

KPI	Reference [%]	Scenario 1 [%]	Scenario 2 [%]	Scenario 3 [%]
Energy consumption	100,00	121,39	149,53	84,80
Grade of waste	100,00	125,81	125,91	64,32
Resource recovery	100,00	102,59	102,01	101,22
Specific biogas yield	100,00	138,68	141,07	67,87
Water recovery	100,00	99,97	99,97	100,04
Product efficiency	100,00	138,68	144,88	227,50
GHG emission	100,00	101,76	114,13	90,95

Scenario 1&2:

- ↑ Biogas yield
- ↑ Product efficiency
- ↑ Energy demand (low grade)

Scenario 3:

- ↓ Energy demand
- ↓ Waste
- ↑ Product efficiency
- ↓ Biogas yield

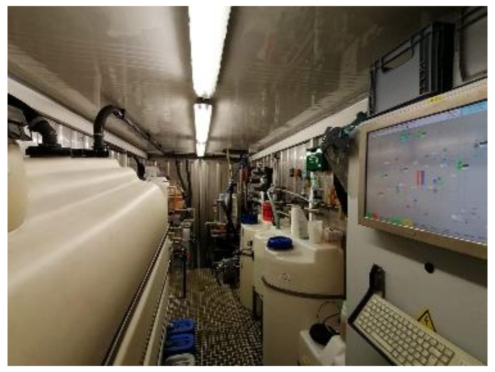
Output = wet cellulose

KPIs to trigger improvements

- Evaluation of combined energy- and resource recovery essential for biorefineries

- Key performance indicators give status quo / state of research → indicate further development options
  - E.g. energy demand increase with MD
  - → new research on ammonia removal < 38°C

- Next steps
  - integration of KPI dimensions in DSS tools like iBio-ref (NR Canada)
  - Socioeconomic evaluation (Johannes Lindorfer, JKU)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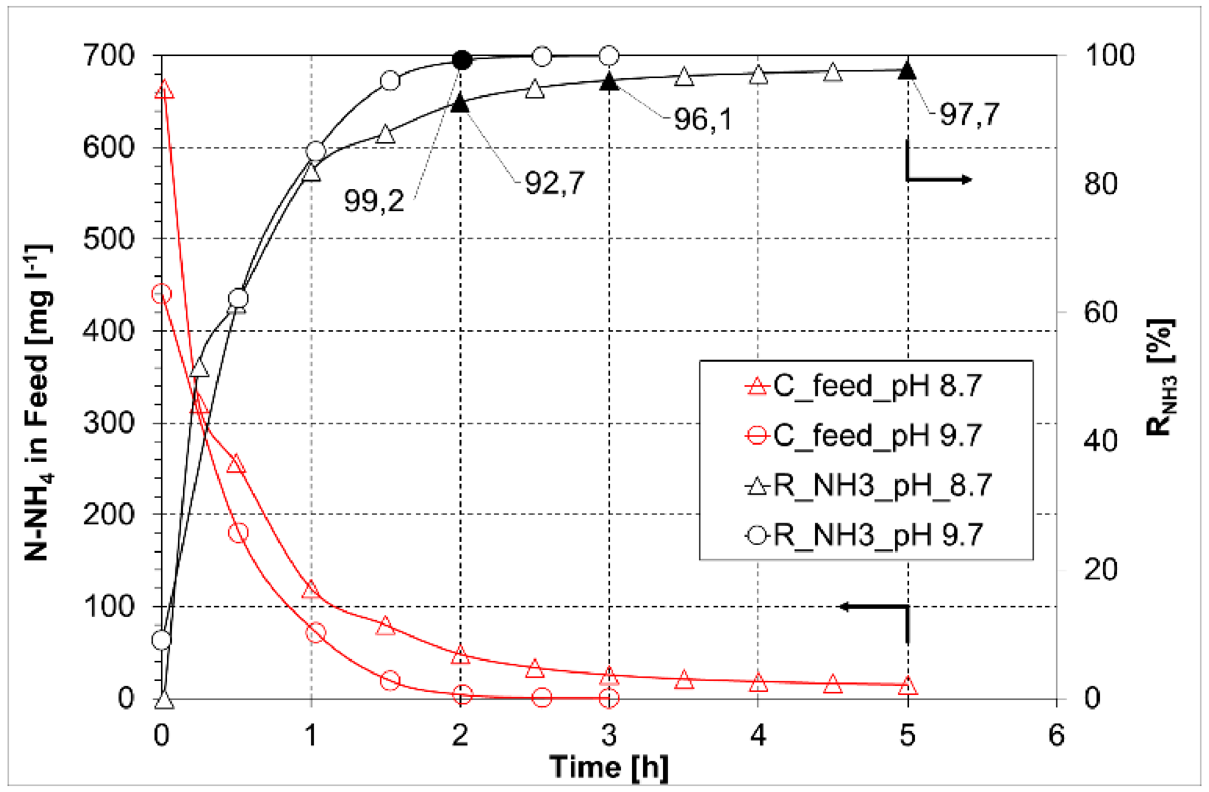
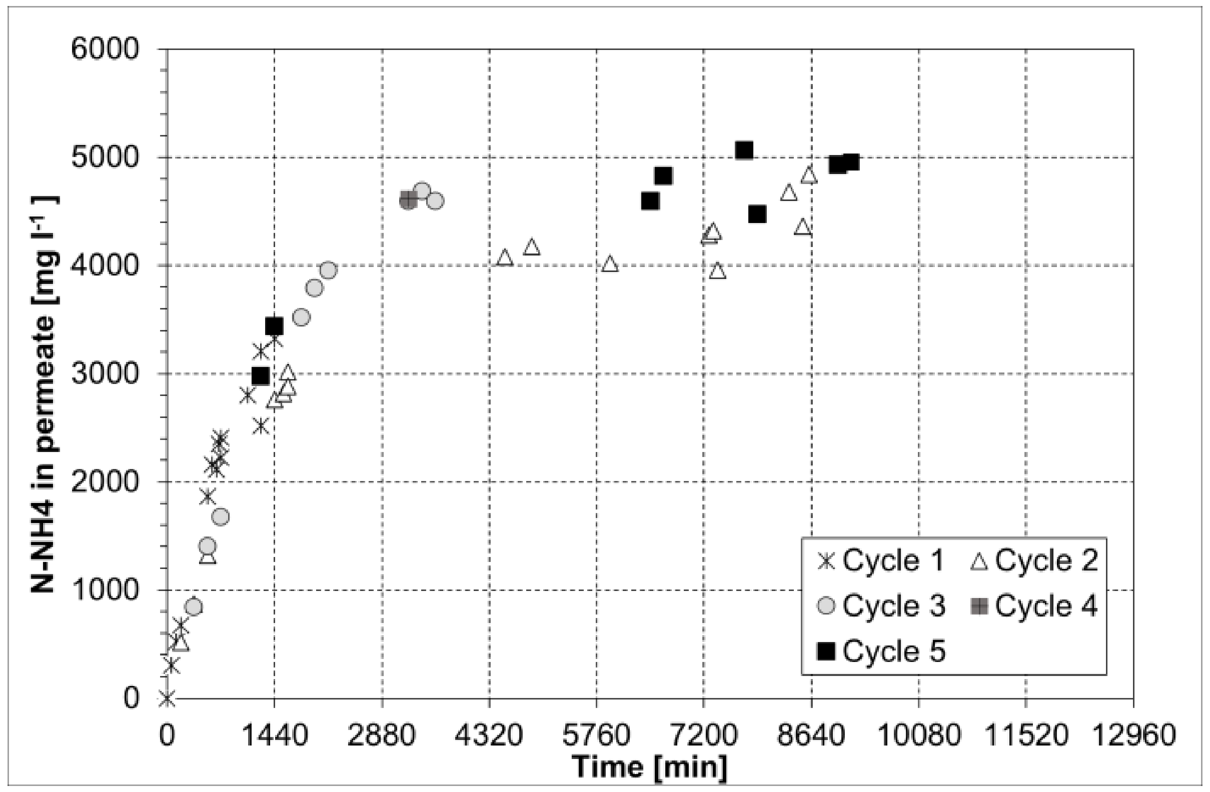
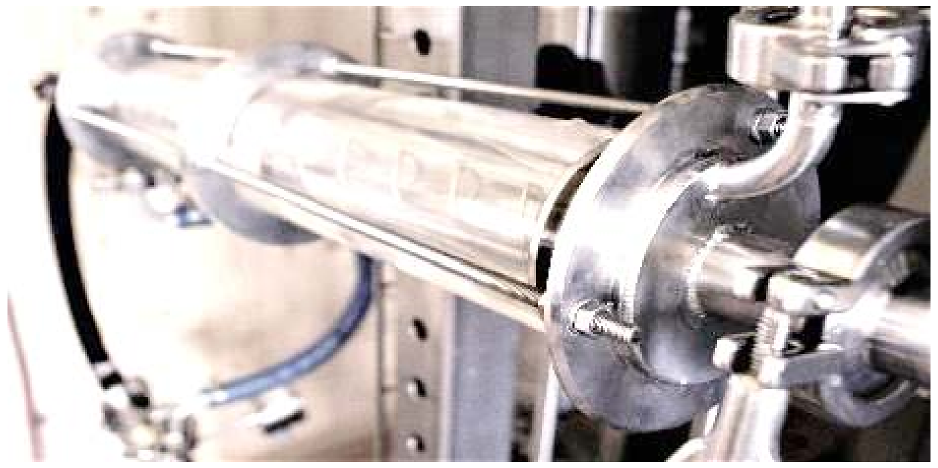




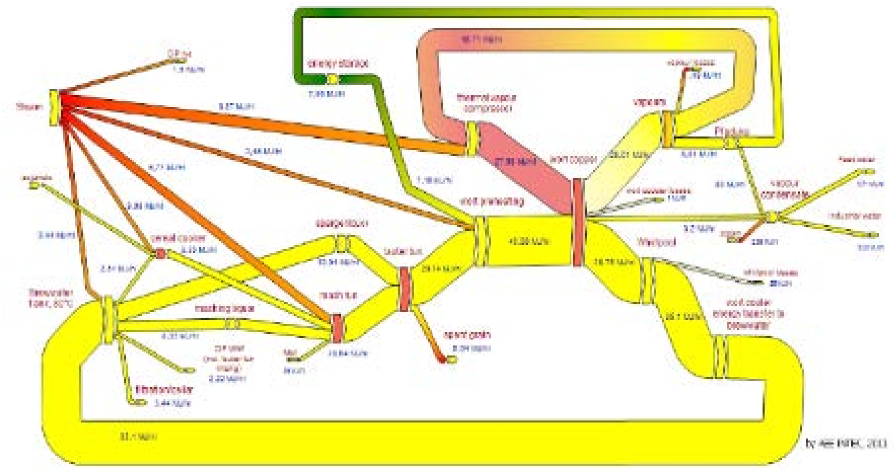
Source AEE INTEC: Guillen et al., 2022 under submission

SUBTASK 2: Net-zero/Negative emission biorefineries

- HIGH EFFICIENT (PROCESS) TECHNOLOGIES; NOVEL REACTORS ENABLE RESOURCE AND ENERGY EFFICIENCY, NEW PRODUCTS
- FOCUS ON IMPACT ON GHG EMISSIONS



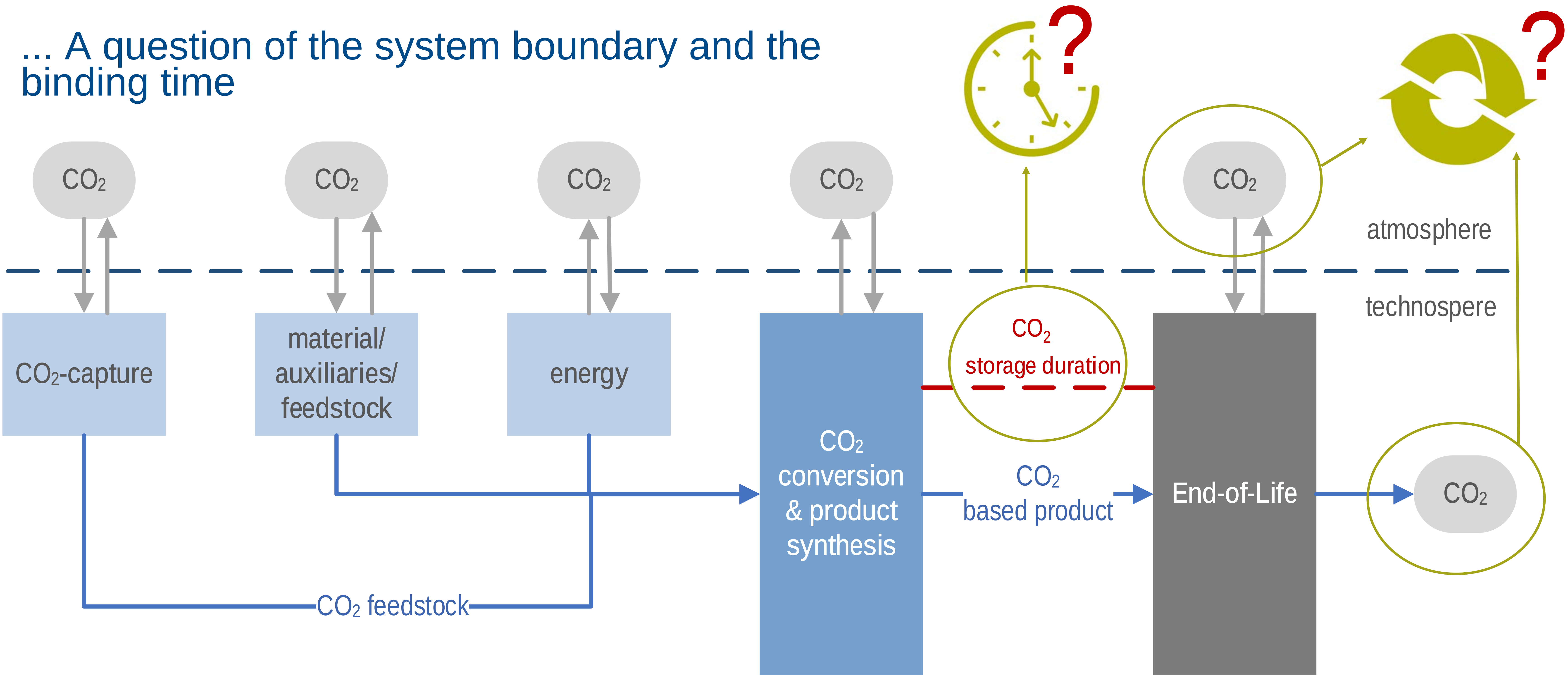
- RE-FRAME PROCESS INTEGRATION TOOLS FOR INDUSTRY-BASED BIOREFINERIES, E.G.
- SITE-ANALYSIS
- PINCH TOOLS



- DATABASE ON BEST PRACTICES ON NEGATIVE/NET-ZERO CONCEPTS

Carbon capture and utilization

... A question of the system boundary and the binding time

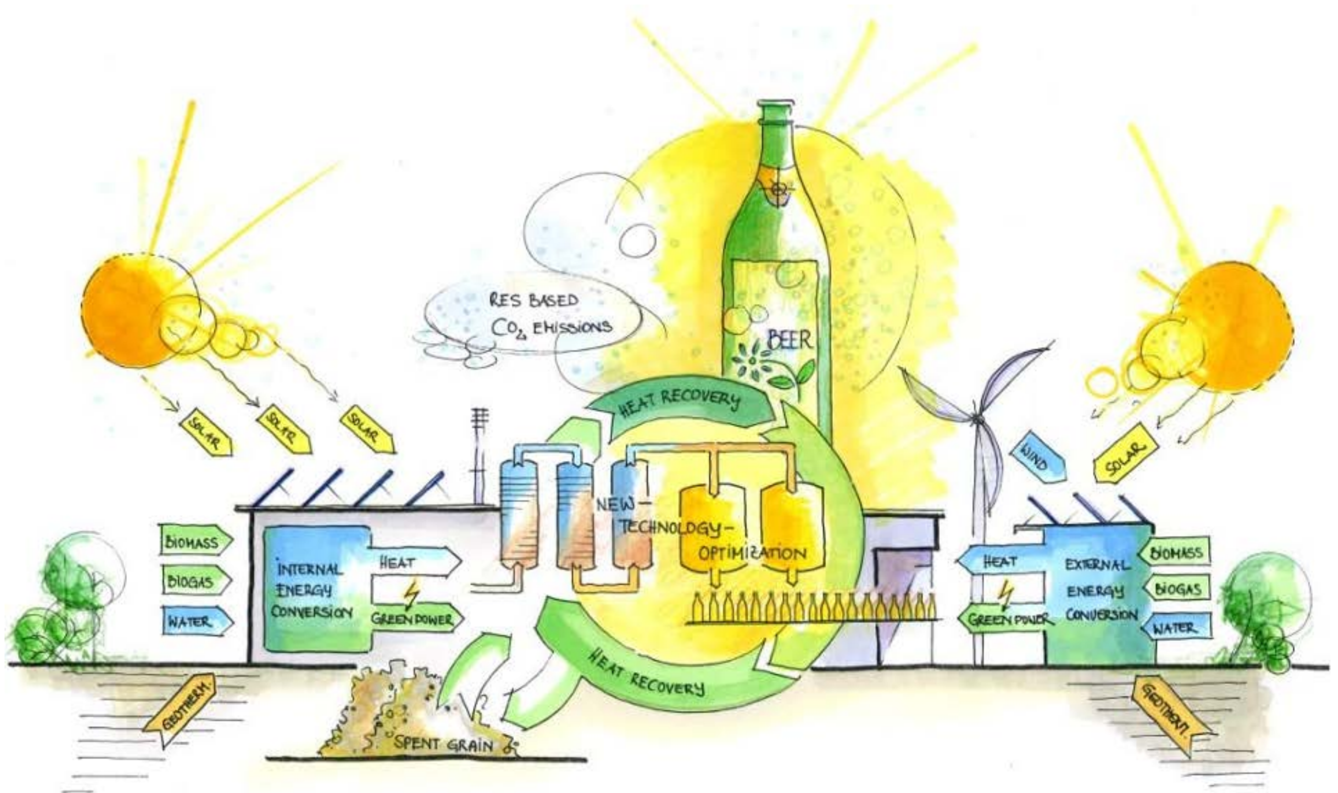


Quelle: Energieinstitut an der JKU basierend auf Zimmermann, A. et al. (2020)

- The energy and material requirements for CO2 capture must be considered.
- Since CO2 from point sources is most likely a "by-product", the results depend on the allocation and expansion of the system boundary.

Case study: Net-zero/Negative emission biorefineries

Climate-positive brewing



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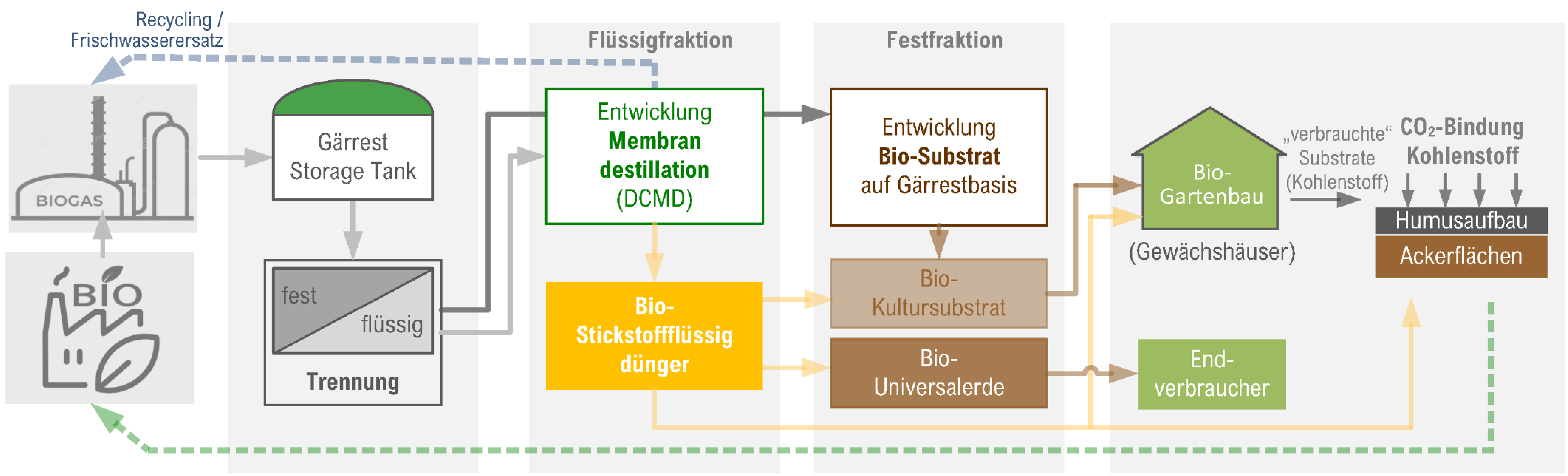

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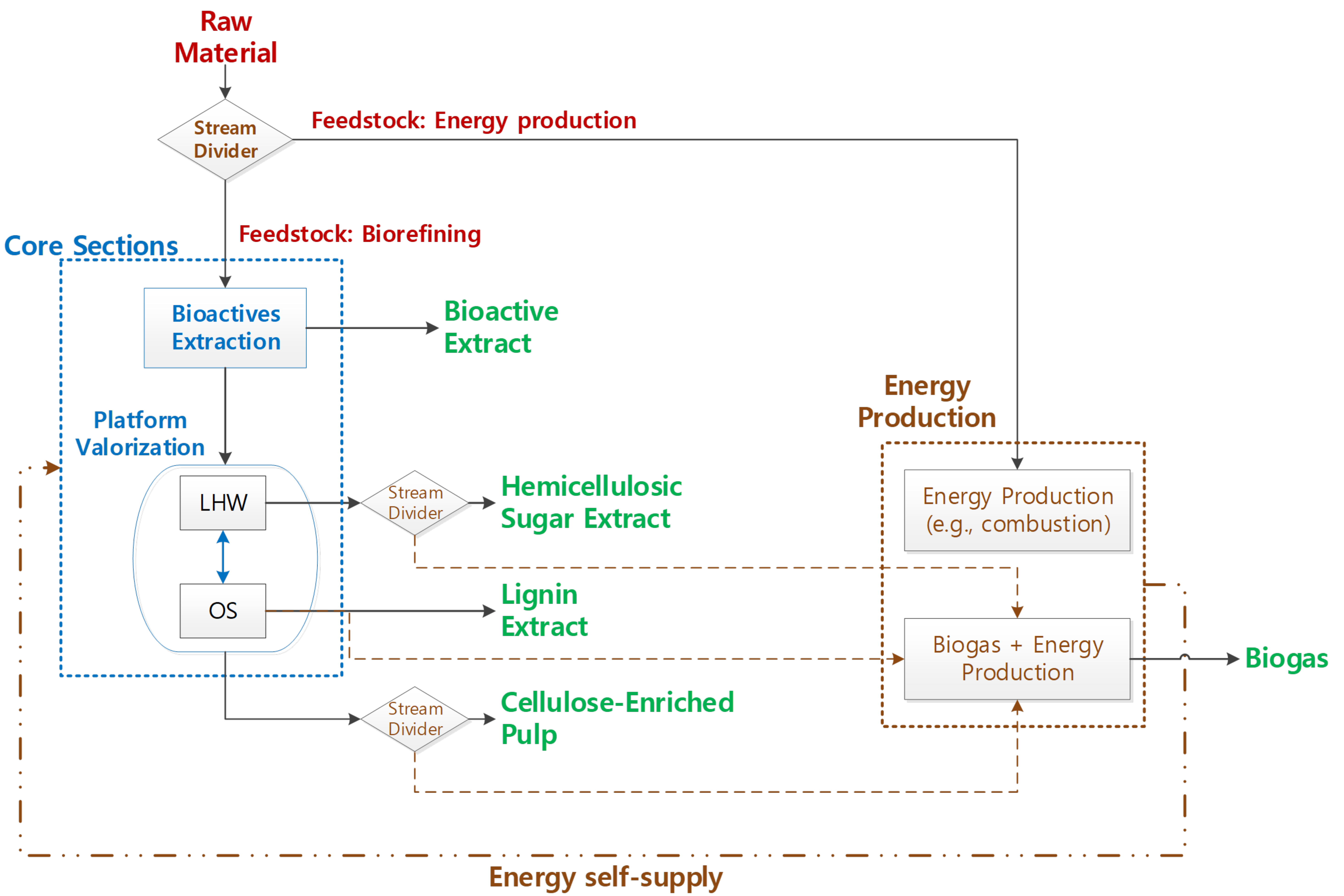
Closing the loop: Towards a self-sufficient biorefinery



Conclusions

- New biorefinery pathways and products are highly important
- Material use of biomass can lead to challenges for energy supply: energy efficiency tools and renewable energy are needed
- Holistic KPIs taking into account dimensions of energy, resource, waste, water, emissions, product….can trigger further (economic) optimization and circular economy
- Use of secondary raw materials is also important in biorefineries to reach circular economy
- Net-zero emission concepts in biorefineries will be elaborated and collected in the future – they might rely on different pillars:
  - **Key technologies** to increase intrinsic process efficiency and/or render secondary raw materials into products (CCU)
  - **Intelligent system concepts** linking diverse process routes
  - **Additional RES-based energy supply** when biobased material is converted into material-products

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IDEA TO ACTION

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